













ENCYCLOPÆDIA  
OF  
CHEMISTRY, MINERALOGY,  
AND  
GEOLOGY.

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## CHEMISTRY.

### Historical Introduction.

Chemistry.  
Definition.

CHEMISTRY is that Science which investigates "the real agencies of the elementary principles of matter." It attempts the resolution of all compound bodies into simple constituent parts; and it examines the action of these elements upon each other, as well in their simple state, as in their most varied forms of combination.

By an *elementary body* we mean a simple substance: one which we are at present unable to separate into constituent parts, having dissimilar Chemical properties. Thus Oxygen, Hydrogen, Gold, &c.; are considered Chemical elements.

It is not always desirable to separate a Chemical compound into all the elements of which it consists, but into certain groups of these elements, each of which groups, possessing definite characteristics, and forming by itself a true Chemical compound, is called a *proximate element*. Thus, for example, sulphuric acid consists of sulphur and oxygen, and these two substances it may be separated, but no further, therefore sulphur and oxygen are called its *elements*, or sometimes, for distinction sake, its *ultimate elements*. But if we take nitrate of lead, it may be separated into nitric acid and oxide of lead, and these two are only called its *proximate elements*: because, by a further analysis, we may separate the nitric acid into oxygen and azote: and the oxide of lead into lead and oxygen. Here then azote, oxygen, and lead, are called the *ultimate elements* of the compound.

Distinction  
between  
Chemistry  
and General  
Physics.

By the definition above given we exclude from true Chemistry the principles of HEAT, LIGHT, ELECTRICITY, and MAGNETISM, as *objects* of investigation, though, as *agents*, some of them are perhaps always present. As *agents* also their assistance is continually required in every department of Chemical investigation. In the excellent *System of Chemistry* by Professor Thomson the former are termed the IMPONDERABLE BODIES, although it is the belief of many that the physical agents of HEAT, LIGHT, ELECTRICITY, and MAGNETISM, in each case, due to the actual presence of a fluid body; yet as the real existence of such fluids has never been fully demonstrated, and as their ponderability, if it exist at all, must be placed at a prodigious distance from that of the most attenuated of our known Chemical elements; we have preferred in this Work to treat of the general operations and effects of those principles (be they of what nature they may) which produce HEAT, LIGHT, ELECTRICITY, and MAGNETISM, under separate divisions; as branches issuing from the great stem of PHYSICAL SCIENCE. Hence, in the Paper now before us, we have only to refer to preceding Treatises for the general doctrines of these *Imponderable Agents*; but as far as they are instrumental in changing those forces which regulate the elementary constitution of matter, so far must this agency be made the subject of estimation and inquiry.

To what extent the researches of future times prove all these agents to be modifications of a universal all-pervading principle, it is not for us to mine: but at present it seems generally admitted that all these subjects gain perspicuity by being treated in separate branches of Science.

Various etymologies have been proposed for Chemistry and its equivalents, in the languages of modern Europe. Besides the  $\chi\eta\mu\alpha$  of Vossius we have noticed in another part of our Work be immediately deduced either from  $\chi\eta\mu\alpha$  the Greeks, or *Alchemy* of the Arabians. If we prove that the Greeks had used the word previously to the VIIIth century, at which the Arabians derived their knowledge of the Science, the Greek writers, it would be evident that they adopted the name also from their teachers. Whether the Arabians (the more modern of the two) obtained their word through or not, it is evident that the words of both have one common origin. Hence the probable etymology is—

Chém, or Kém, that which produces both fire and life, or Kém, the indigenous name of Chemia, or the Egyptian Art, as it was called by the Greeks, may have been transcribed Kémia by the Arabs, and the article which they frequently have retained in the Latin version of their writings made in the dark Ages, as an introduction to the word Alchemy.

Having thus described the object of the present treatise, we may proceed with a very brief statement of the origin and progress of our Science. The liberty in which it was necessary to stimulate the mind of the reader, or to awaken his interest in him that almost all the phenomena of nature in some shape or other to be traced up to Chemical principles; we need not remind the manufacturer of manufactured goods, that in a greater proportion of those operations, by which species of the produce of nature is converted into other form, better suited to the wants of mankind, Chemical affinities are employed. The value of this study; and the reasonable advantage to be derived from it, is that it forms a skillful calculation of effects arising from ascertained causes: all the old processes which might be expected from the rudest tent unguided by Scientific principles or industry. To Chemistry, the Science of Medicine owes under the deepest obligations. The medicines have for many years been derived from natural substances, which have undergone purifications and ameliorating combinations. Chemistry alone can devise and execute, in particular, the same powerful Science is prepared to work a further change: in numerous experi-

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in ten years been made upon the most of the vegetable tribe in the *Materia Medica*, these it would seem that it is possible, in very cases, to separate the active medicinal principle from the ligneous and inert matter by which it is mixed, and to present it in a pure crystalline form. In this process two objects of considerable importance are attained: the one, that the woody matter (in the case of bark) frequently disordered the action is got rid of; and the other that the uncertainty of the strength of dose, which in vegetable medicines varied greatly, is altogether obviated. There are other minor advantages of portability, &c.; but by no means unworthy of attention in a science of such extensive public importance.

Chemistry, according to the definition we have given, is but a Science of very recent introduction: it is only to be said to have existed two hundred years. It is been usual to connect its History with that of Natural Science, possessed of considerable similarity of its processes; though differing widely in the objects at which its professors aimed. Every labourer in Chemistry and all his ingenuity was directed to one or other of the following objects: the transmutation of the baser metals into gold; or the discovery of an universal medicine, which should cure all progress of all disorders incident to the human frame; and thus prolong the life of the successful to an indefinite period of duration. Of the labours of the Alchemists there are abundant records. Numerous manuscripts yet exist in extensio-aries, especially in those of Paris and Leyden, and in the libraries of the Press as well as in the

Arabic, in Latin, in the Press of modern Europe. Besides this, there are with its thousands of volumes of this description, the XVIth and XVIIth centuries: and, by perusing some idea of the prolific industry of the Alchemists, we may mention that Petrus Borellus has a catalogue of more than four thousand such works up to the year 1654. It is to be remarked, that in this catalogue he has admitted the many Alchemists whose works have never been published, and perhaps never committed to paper: on the other hand, the list might be greatly increased by names which he has omitted, or which had been red at the time of his publication.\* The labours of the Alchemists, though not altogether of perusal, are of very various degrees of some we may trace the bold impostor, who would declare that he possessed powers and which he must have known that he had not; who attempted to make a gain of the credulity of the public, had he really been able to effect the *opus magnum*; or other evidences would have been brought in a mere appeal to the liberality of others to the fire of his furnaces. In others we find impatient, mindless plodding of those who endeavoured to follow instructions of such studied folly, that at each successive failure the unhappy only thought that he had misunderstood the words of his master; and never suspected the want of sincerity of the guide he was blindly following. In this crowd of writers there are, indeed, a

few deserving higher estimation, men who worked industriously and described faithfully their attempts, their failures, and consequent disappointments. Had the labours of this class been guided by any thing but inductive reasoning, or had they even studied to try the substances upon which they operated, as a du-ly as they did to vary the mode of their operation and the forms of their apparatus, we might even look back to their writings for experimental results, indeed, and devoid of order; but still valuable as recorded facts. Instead of this, however, the best of them went on torturing the same vegetable quicksilver, with precisely the same operation times repeated: and subjected the same portion of spirit of wine to three hundred consecutive distillations. Can we wonder then that the latest Alchemist, as he rigidly persevered to walk in the steps of his predecessors, should in reality be as far from having any true chemical knowledge of the constitution of nature as Gabelius or even Hermes himself.\* It would appear, further, that much as the Alchemists professed to reveal of their Arcana, each one was unwilling to put the rest of the world in full possession of any thing of value at which he might have arrived. This might in part arise from a desire which many of them obviously possessed of inducing a general belief in the superiority of their own individual attainments. Thus Roger Bacon, a man second to no one of his day in all that then constituted learning, and of consummate ability, yet when he describes (as we fully think he does describe) the preparation of gunpowder, names at once the *salis petrae* and *sulphuris*, but conceals the remaining ingredient, the *carbonum pulvere*, under the anagram of *luru mone cap urbre*.

We may smile at the pertinacity with which the Alchemist pursued his lengthy processes of cohobation and digestion, through wearisome days and sleepless nights, wasting his money and wearing out his vessels with perpetual fires: and, perhaps, it is lawful to express some little surprise that the repeated failure of his hopes, and the evidence of his own experimental facts, did not force upon him this obvious truth; that the thing he sought was impossible or impracticable. But in his defence he it said that he had abundance of attestation that others had actually succeeded in the process of transmutation; and the studied obscurity in which all the instructions of the most celebrated adepts were enveloped, might always leave him in doubt whether his failures were not chargeable to his own misapprehension. Besides, there were, in favour of the possibility of transmutation, some simple and well known experiments which had wonderfully the semblance of such an operation. Such, for instance, is the precipitation produced by dipping a polished iron rod into a solution of a salt of copper.

Many adepts professed to have obtained the secret of metallic transmutation, and, by the help of good legerdemain, some well attested instances of their successful operations are on record. Few, however, were like Paracelsus, bold enough to profess to have found out the *Elixir of Life*, the *Universal Medicine*. It is needless to say that these few gave rather an unfavourable attestation to their roguery or credulity, by submitting, like their neighbours, to the common lot of mortality. Yet even these were not quite without a reason in their folly; for, in the first place, the operations of Chemistry had, recently, so pre-

\* best estimate that we can form, the Alchemical literature is to about one thousand; and their Treatises to about number

the origin of their craft, and several authors who felt that many of the processes of the art dependent upon Chemical agencies, thought that they were the result of Chemical knowledge. In grounds, Tubal Cain, the first artificer in iron, has been considered the father of Metallurgy. There is also a story in Yonah, which Tertullian, that the knowledge of Chemistry was among the gifts bestowed by the Angels, led from heaven by the beauty of the daughter earth. Others, more moderate, deem Noah a Chemist, because he is said to have discovered of making wine. Ham, the son of Noah, and his descendants, to whom the Arts and Sciences seem to be a heritage, are thus celebrated by Voltaire, for instance, says, Si Mezraam fils de Noé exerça pas lui-même la Chémie, l'on croit du moins qu'il la fit exercer par son aîné Thaut ou Cham, nomme aussi Hermes ou Mercure, que devint le Dieu Thebes Cham porta donc, vraisemblablement, en Egypte, ou du moins son fils Mezraam, et que nous la royons se répandre dans l'univers.

Et sur ce que Noë a eu des enfans à l'âge de 600 ans, j'en dirai pas comme a fait Vincent de Beauvais. Neveu du saint Patriarche a pratiqué lui-même la Chasse, la Pêche, la plus parfaite, et qu'il a eu la Médecine universelle, la partie la plus sublimé de la Philosophie. Hermetique il suffit de la donner à Cham, ou à ses descendants, qui cultivèrent en Egypte, avec beaucoup d'autres sciences, inconnues au reste de l'humanité. Et si l'on veut croire que l'ouvrage, rapporté dans les MSS, est de cette science sous le nom d'Isis, fut de cette Prière, seroit assurément l'antiquité de la Philosophie. Toi qui dis, pourqu'elle étoit l'épouse d'Onuris, qui étoit Hécate, how-Mezraim: ainsi la pratique de la Science Hermetique, pourroit remonter à plus de 25 siècles avant l'Ere chrétienne. Mais je ne porte pas si loin ma prétention, et j'absolue donc de la rapporter à Hermes ou Mercure, et à l'anthropologie Trismégiste." (*Hist. de la Phil. Hermet. p. 1.*)

## Origin of Alchemy

M. Dupin also asserts, that "several Jews have observed books which they have fathered upon The Prefixed to such, for instance, as the book entitled The Ge and Creations of Adam. It was a common superstition, among them, that Adam composed a treatise, eccle, and ing the Philosopher's stone and there is a temporary. Magic which is thus attributed to Cham, of wists of the sius makes mention." (Eccles. Hist fol. ed. and a reprint

We advance then to the second *Hermes*, "will show *Trismegistus* a personage who has always been regarded with peculiar veneration by Alchemists the more subsequent Age. SIFHOAS, king of Thebes andphis, who lived about two thousand years (it is the commenced, according to Du Fresnoy, a c. 19th in vain, the Christian era, was celebrated for great at of his con in the Arts and Sciences, known to the Greeks under name of *Hermes* (*Mercurius*) *Trismegistus*, a pseudonym, usually considered the founder of Alchemical Science, thence has been frequently termed the *Wern of Mayow* Tertullian styles him *Phynocrorum Magister cele*. The Treatises, attributed to him, have been published in 1650, more yet remain in manuscript; but it is the diffusion, belief that not one of these is the genuine in both Sirrhoas.

From Egypt, then, it is really probable that of weight  
 metic Philosophy might pass to the Israelitish nation.  
 Moses has been claimed as an adept, because, in the  
 recorded to have been skilled in all the learned in the



as. The Greeks also derived their knowledge from the same source; and, passing by the names of the Persian, and Ostanes the Mede, who lived in the time of Xerxes, we arrive at Democritus the philosopher, who lived in the 5th century before Christ. There are several manuscript copies of a Treatise attributed to this author, which Treatise has been translated, together with an ancient Commentary by the Bishop of Ptolemais.

Comarius or Comanus, an Egyptian Priest, there is a treatise on Alchemy in Greek. He lived about 300 years and is said to have instructed Cleopatra in the Hermetic Science. There exist also Treatises which are supposed to have been written by this queen, and the use of a pearl to form a costly potion, is adduced as one of her Philosophical attainments.

The Hermetic Science had passed into Rome also. Pliny informs us (lib. xxxiii. cap. 4.) that Caligula attempted transmutation on a large scale: *et planè fecit opus, sed ita parvi ponderis, ut detrimentum*

no check was, at length, given to the pursuits of Alchemy in Egypt; for we are informed that Diocletian, who caused the Hermetic writings of the Egyptians to be collected and burned: supposing that it was by the use of the gold thus fabricated, that they were enabled to supply their rebellions against his empire. If any manuscripts of importance escaped destruction, it is probable that they subsequently perished with the thousands of others destroyed at the Alexandria by the Saracens, under the Caliph

Alchemic fire, however, if we may believe its use, still continued to burn steadily if not increased, and the following series of writers is mentioned, as having left Treatises which

Porphyry, a Christian Philosopher, A. D. 176. *De Amour*, printed at Paris, 1599 and 1612.

Bishop of Ptolemais, A. D. 410, left Greek Treatises on Alchemy, and his Commentary on Democritus in *Fabricii Bibl. Græc.* tom. viii. Heliodorus, of Tricca in Thessaly, A. D. 405, printed in *Bibl. Græca*, tom. vi. Zosymus of Alexandria, numerous Treatises in MS. Archelaus, MS. Pelagius, A. D. 420, MS. Olympiodorus, MS. Theophrastus, A. D. 450. A Christian Philosopher, *De sacrâ et divinâ arte*, MS. Stelephandria, A. D. 630, MS. Pappus, a Christian Philosopher, A. D. 638, MS. Cosmus, a Monk, A. D.

to trace the origin and progress of Chemistry, the general belief is, that previous to the Mahomet, the Arabs entirely neglected the use of Philosophy of every kind. "During the reign of their fourteen first Caliphs, viz. from 632 to A. D. 748, they were solely employed, like the Persians, in preserving the purity of their language, in the study of the Koran; with the addition of medicinal knowledge, which they found a practical utility."

An attempt for every species of Science which the use of Mahomet long retained, has been illustrated by the following well known anecdote, which is related by Du Fresnoy. "Amru, the Arabian Philosopher, having made himself master of Alexandria, he found in the celebrated city a Library well

stored with numerous Philosophical writings. John Philoponus, an able commentator on Aristotle, was then a teacher in that city. He requested the Mohammedan General to grant him all the Philosophical works which might be found in the Library. Amru dare not take upon himself to make this present to Science. He therefore wrote for instructions from Omar, the second Caliph: but the answer which he received was fatal to the works and to Science. The Caliph remarked that if the writings were found contrary to the Koran, they must be destroyed, as being pernicious: but that if they were conformable to its dogmas, they became useless, as the Koran was all-sufficient. Thus none were preserved; all underwent one common fate and were destroyed. They were employed in heating the baths at Alexandria, and were more than six months in being consumed, though there were then more than 4000 baths in the city."

The dynasty of the Abbasides was, however, more favourable to Science. "Almansor, the second, and Haroun al Rasched, the fifth Caliph of that race, were its able promoters.

In Bishop Pocock's translation of Abul Farraj, we find that Mamun Ben Rasched, (who lived A. D. 813,) "*amabat scientias et sapientes ac viros celebres: ejus tempore translati sunt multi libri ex Græcâ linguâ, in linguam Arabicam.*" p. 246. It is to this period that we think we may justly refer the passage of Chemistry (such as it then existed) from the Greeks to the Arabs.

The following may serve as a brief note of some Arab Alchemical writers mentioned by Borrichius and Du Fresnoy. A MS. in Arabic, in the Library at Leyden by Ostanes: M. Du Fresnoy considers this a translation from the Greek. The Commentary of Eddim Ben Ali on Abul Hassam, and the Treatise of Gelladek are both in the same depository. Geber who, after Hermes, is in the greatest repute with the adepts, left many Treatises. Borrichius supposes him to have lived prior to A. D. 830. His works were imperfectly printed until 1682, when a correct edition appeared at Dantzic, copied from a MS. in the Vatican. The next cited, in chronological order, is Rhazes Jr Mohammed Ben Zakaria of Korbassan, who died A. D. 932. He has the reputation of having first applied Chemical Science to the *Materia Medica*, and was an expert Physician. Farabi was a great traveller, and is reputed to have acquired a large and varied fund of Philosophical knowledge. He was murdered by robbers in the woods of Syria, A. D. 954. His works, which are numerous, are stated to be in MS. in the Library at Leyden. The time at which Michael Psellis lived is not certain, he was of Constantinople. Leo Allatius de Psellis, &c. Roma, 1634. There is a pretty little story made out of the history of Adfar, a sage Arabian adept. Morienus, a Roman, left his Country for the sake of participating in the Hermetic learning of Adfar and Kalid, who is reported to have been a Caliph or Sultan of Egypt; to these Morienus communicated the *arcana magna*, and then mysteriously withdrew himself from Royal favour, returning to his original solitude in Jerusalem. Morienus's Treatise was written in Arabic, but translated into Latin by Robertus Castrensis, A. D. 1182. Morienus is supposed to have lived at the middle of the 11th century; he was much younger than Adfar, and probably rather older than Kalid. The translation of a work referred to Kalid, may be seen in Mangetus.

The last Arabian writer whom we need cite is Ebn

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## European Alchemy

Returning now to the XIth century, beyond which we had rather advanced for the sake of completing the Arab part of our History, we find two causes tending to introduce the Sciences of the East, and therefore Alchemy, into Europe. First, the Crusades; which commencing towards the close of the XIth century, carried numbers of Europeans into the East to combat the Saracens; from which countries, those who returned, brought back with them the knowledge of many Arts unknown to their forefathers. Thus may England, France, and Germany have gained the knowledge of Alchemy. The Latins might possibly have before acquired some knowledge of the Hermetic Art from the Greeks; but if not, there was the second cause to which we have alluded, viz, the conquest of Constantinople, (A. D. 1205,) by which they would become possessed of many Alchemical Treatises, and in which city they must have found artists actually employed in their processes.

*In England.*—**Roger Bacon**, a Franciscan Friar of Oxford, 1260. **John Cremer**, Abbot of Westminster, 1312. **John Daustein**, 1315. **Thomas Dalton**, a priest of Gloucester Abbey, 1450. **Sir George Ripley**, Canon and Carmelite Monk, 1471. **Thomas Norton** of Bristol, 1477. **Thomas Charnock** of Salisbury, instructed by Sir James S—, a priest living in the cloisters near Salisbury, 1574. **Pierce the black monk** in the XVth century. **Dr. John Dee** of St. John's College, Cambridge, Chancellor of St. Paul's, 1595. **Edward Kelly**, a Notary, born at Worcester, 1555. **Alexander Sethon** of North Britain, 1602. — **Butler**, an Irish gentleman, 1624. **Eireneus Philaethes**, 1645. **George Staikov** of London, 1646.

*In Italy.*—St. Thomas of Aquino, 1260. Ferarius, an Italian Monk, 1320. Pope John, XXII. of Avignon, 1330. John de Rupescissa, a Franciscan Friar, 1350. Peter Bona of Lombardy, 1337. Bernard, Count of Treves, of Padua, 1491. John Picus, Count of Mirandola, 1491. Claude Berigard of Pisa, 1641. Joseph Balsamo a Sicilian, 1788

To these add Alphonso, King of Castile, a. Raymond Lully, Seneschal in Majorca, 1265, and Isaac, Jews of Holland; 1420. J. B. V. mont, a Physician in Flanders, 1599. F. H. M. D. in Holland, 1666.

In concluding this very brief sketch of the history of Alchemy, it would have been possible to cite Alchemical writings of a date still more recent than these above mentioned. In fact, we are extremely probable, that there may be persons living, who believe in Alchemy, and even pursue visionary prospects it holds out. Some there are too, who despairing of obtaining the Elixir of Life in the universal medicine, nevertheless, led by false assertions and false analogies, are in hope of attaining to the transmutation of metals. Or, perhaps, some might with one of the later English writers, avoid the term transmutation: he says, "It is never in very deed a chaos which is related to all things; towards the mother; for out of it I know how to extract at which the even gold and silver without the transmutation of which the thing which whosoever doth also see, may be come to testify it." Page 5 of "*Secrets revealed*," a most famous Englishman, styling himself: Alchemist or Eyræneus Philaletha Cosmopolita; who, by study and reading, attained to the Philosophy of Nature at his age of 23 years, A. D. 1645." To this we ought of this Adept's sentence we fully subscribe, and we are, however, extremely

It has been remarked, that many of the Philosophers were Ecclesiastics of different ranks. This does not seem strange when we consider that in the great an extent Learning was confined to the clergy, and the periods to which we now refer. There run through many of the Alchemical writings a strong vein of mysticism, which has frequently every appearance of being sincere. Prayers, and fastings, and almsgiving, frequently essential parts towards the attainment of the magick, and there is every reason to believe that by temporary, and strictly performed. We cannot be surprised at the finding the mystic Divines involving Alchemy in their speculations; and it may be somewhat singular, though we feel it rather an humiliating specimen of human mind, to produce a passage or two which were published in England so late as the year 1811.

"ATTRACTION is the first principle of job it (the nature: the origin of attraction is beyond the vain, is therefore incomprehensible to the human understanding. REPUSSION is the second principle: it is the necessary consequence of the first by reaction. REJUDICE, or REPROBATION is the third principle: it proceeds from the first and second, they are the effect of the attraction and repulsion." This of Mayow author seems to think developed in five models. The matter, wherein the ALKALINE is fully described its explanation, illustrated by a most sublime diagram, which, in the light of the caricature representation of the genital in both chemical processes. The author concludes, in the mechanical part of these principles pass, of weight hands of its proper manufacturers, equally calculation, rally in all Countries, and that all Governments; that for the alteration; the school, of the Adversary in the

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it of his captivity in Babylon, and they will find us, upon level as true Physicians for the soul and dispensing the leaves of the tree of life for the the of the nations." It may be fair to state, that immo professes himself indebted to the writings of his teachers for these his first principles. All we say is, that the pupil seems to have been well instructed by his instructor.

"Tribus Anticyris caput insanabile."

Alchemists did not disdain the flowers of Poesy, a magnificent mode of conveying their instructions. Of a trying we confine ourselves to the introduction of ban, specimens.

But holy Alchemy of right is to be loved  
Which treateth of a precious medicine,  
Of such as trewly maketh Gold and Silver fine  
Of whose example for testimonie  
Is seen in a City of Catalony  
Which Raymond Lully, knight, men suppose  
Made in seven images, the trewth to disclose;  
One of three were good silver, in shape like ladies bright,  
Whose every each of four were gold and did a knight  
On the borders of their clothing like appeare,  
E precluding in sentence as it sheweth here.  
The old horse-shoes (said one) I was yre,  
To the cow I am good silver, as good as ye desire  
The lewas (said another) iron fet from the mine,  
Now I am good pure, perfect, and fine  
The bilon was I copper of an old red pann,  
Now I am good silver said the third woman.  
The fourth said, I was copper grown in the filthy place,  
Now am I perfect gold made by God's grace.  
The fifth said, I was silver, perfect thorough fine,  
Now am I perfect gold, excellent, better than the prime.  
The sixth said, I was a pipe of lead well nigh two hundred years,  
Now to all men good silver I appear  
The seventh said, I leade am, gold made for a maistrie,  
I preclude my fellowes are nether thereto then I  
From *Journal of Alchemy in Ashmole's Theat. Chem Brit* p. 20

Following may serve as a specimen of the language adopted by the Adepts, for the purpose of giving their processes from the uninitiated vulgar purpose the metals were spoken of by many designations; a method which first originated in the most remote antiquity. Thus the Sun, Apollon, and the sign ☉ was found to stand for Apollo, in the margin of an early MS. Silver was the Moon, and so of The passage further shows the early use of amalgamation.

yet more kindly som other men don  
mentyng theye Medecynes in thys wyse,  
Mercury dissolvynge both Sou and Mon.  
&c &c  
other ther be which hath more hap  
touch the trolle in parte of Fermentinge,  
of Amalgam ther bodyes with Mercury like papp  
see Ripley's *Compound of Alchymie* in Ashmole's *Theat.*  
um, p. 171.

we here conclude our notice of the Alchemists however, to be by this understood that the the Hermetic Philosophy fell suddenly into disuse, but that as the writers with which acquainted at the beginning of the XVIIth imbibed from Bacon a more just spirit and investigation, they gradually converted the of undigested facts, collected by the Alchemists into the foundations of a regular Scientific inquiry substitution of nature, and the agency of these forces upon matter. Of the last English

Alchemists, we know of no other account than the following, given in the History prefixed to Mr. Brande's *Chemistry*, vol. i. p. 25.

"In later times we have had two or three believers in transmutation. In the year 1782, Dr. Price of Guildford, by means of a white and a red powder, professed to convert mercury into silver and gold, and is said to have convinced many disbelievers of the possibility of such change; his experiments were to have been repeated before an adequate tribunal, but he put a period to his existence by swallowing laurel-water."

"Another true believer in the mysteries of this Art, was Peter Woulfe, of whom it is to be regretted that no biographical memoir has been preserved. I have picked a few anecdotes respecting him from two or three friends who were his acquaintance. He occupied chambers in Barnard's Inn while residing in London, and usually spent the summer in Paris. His rooms, which were extensive, were so filled with furnaces and apparatus, that it was difficult to reach his fire-side. A friend told me that he once put down his hat, and never could find it again, such was the confusion of boxes, packages, and parcels that lay about the chamber. His breakfast hour was four in the morning: a few of his select friends were, occasionally, invited to this repast, to whom a secret signal was given by which they gained entrance, knocking at a certain number of times at the inner door of his apartment. He had long vainly searched for the Elixir, and attributed his repeated failures to the want of due preparation by pious and charitable acts. I understand that some of his apparatus is still extant, upon which are supplications for success, and for the welfare of the Adepts. Whenever he wished to break with an acquaintance, or felt himself offended, he resented the supposed injury by sending a present to the offender, and never seeing him afterwards. These presents were sometimes of a curious description, and consisted usually of some expensive Chemical product or preparation. He had an heroic remedy for illness: when he felt himself seriously indisposed, he took a place in the Edinburgh mail, and, having reached that city, immediately came back in the returning coach to London. A cold taken on one of these expeditions, terminated in an inflammation of the lungs, of which he died in 1805. He is the author of several papers in the *Philosophical Transactions*."

We conceive that our time may easily be employed more advantageously to our readers, than by repeating here the histories and attestations that have been handed down to us in favour of successful transmutations. Such, however, may be seen in the works of Boyle and Boerhaave. There is also an amazing tale of the kind in Helvetius's *Golden Calf*. The following, however, has been pointed out to the writer of this Paper by a friend, and is given as, perhaps, the latest recorded instance of expert juggling of this kind; especially as it proves that there are yet followers of Alchemy in the East.

"A few days before my arrival at Bassora in August, 1814, (says Major Macdonald Kinneir,) Mr. Colquhoun, the acting resident at that place, received a message from an Arabian Philosopher, requesting a private interview, in order to communicate a most important secret. Mr. C. consented; and next morning the mysterious stranger was introduced to him: embracing the knees of the resident, he said he was come to supplicate the protection of the English from the cruel and continued persecutions of his countrymen, who, having

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understood that he had the power of transmuting the basest metals into gold, daily put him to the torture to wring his secret from him. He added, that he had just made his escape from Grane, where he had long been starved and imprisoned by the Sheck, and that he would divulge every thing that he knew to Mr. Colquhoun, provided he was permitted to reside in the Factory. My friend agreed to receive him, and in return he faithfully promised to afford a convincing proof of his skill. He accordingly retired and soon afterwards returned with a small crucible and chafing-dish of coals, and when the former had become hot, he took four small papers containing a whitish powder from his pocket, and asked Mr. C. to fetch him a piece of lead: the latter went into his study, and taking four pistol bullets, weighed them unknown to the Alchemist: these, with the powder, he put into the crucible, and the whole was immediately in a state of fusion. After the lapse of about twenty minutes, the Arabian desired Mr. C. to take the crucible from the fire, and put it in the air to cool: the contents were then removed by Mr. C., and proved to be a piece of pure gold, of the same weight as the bullets. The gold was subsequently valued at 90 piastres in the Bazar. It is not easy to imagine how a deception could have been accomplished, since the crucible remained untouched by the Arab after it had been put upon the fire; while it is, at the same time, difficult to conceive what inducement a poor Arab could have had to make an English gentleman a present of 90 piastres. Mr. C. ordered him to return the next day, which he promised to do, but in the middle of the night he was carried off by the Sheck of Grane, who, with a body of armed men, broke into his house and put him on board a boat, which was out of sight long before day-break."

Alchemy in China.

—*Travels in Armenia, Koordistan, &c.* p. 406.  
We have, hitherto, passed by the claims of the Chinese to an early knowledge of Alchemy. Martini in his *Historia Siniæ*, and Le Comte in his *Mémoires sur la Chine*, state that the Chinese assert Alchemy to have been known among them 2500 years before the Christian æra, but that they have no manuscripts on the subject. In the *Mémoires de l'Acad. de St. Petersb.* for 1807 and 1808, vol. ii. there are some extracts from a MS. on Chemistry, brought from China by M. Bournon. The title, when translated, runs thus: *Confessions du paisible Dragon*, composed by Maô-lihoa in the reign of the Emperor Souï-dsouinn of the dynasty of Tann, which is equivalent to A. D. 756.

In the first chapter the author says, "Tout ce que l'homme peut sentir et observer par les sens, et tout ce qu'il peut concevoir par son esprit et par son imagination, est composé de deux principes fondamentaux le Yann et la Yne, qui désignent le parfait et l'imparfait. Le Yann est le puissant ou l'accompli, et le Yne lui est diamétralement opposé."

Of the Atmosphere (Hhiá-chénn-kí) he says; this Hhiá-chénn-kí is the kí which rests on the surface of the earth, and elevates itself to the clouds. When the proportion of the Yne which makes part of its composition is too great, it is not so perfect as the kí beyond the clouds. We might perceive the Hhiá-chénn-kí by the sense of touch, but the elementary fire with which it is mingled, renders it invisible to our eyes. There are many methods which purify it and deprive it of a part or its Yne. This is done by substances which are modifications of Yann, such as metals, sulphur (lieôu-khouann,) and Tane, or charcoal. These ingredients,

when we burn them, amalgamate themselves with the Yann of the air, and give new combinations of the fundamental principles.

On the whole, although we suppose it just that the pursuits of Alchemy may have extended themselves into China, yet there seems little evidence on the subject. We have almost felt it a waste of time to notice M. Bournon's MS., for it is in perfect accordance with the well known character of the Chinese, of vising such frauds, and for great skill in executing, to suppose the whole a forgery, the object of which has been to produce an evidence of Chemical knowledge having existed among them, prior to its appearance in Europe. Thus they would pretend that the composition of the atmosphere, and the nature of its ingredients, was known in China during the VIIIth century, and as com- cisely as explained in Europe at the close of the XVIIIth.

### History of Chemistry.

We have admitted that it is to the medical pursuits of the XVIth century, that we are indebted for the pursuits of Alchemy into those of true Chemistry. The knowledge which the Adepts had gained, by their unwearied efforts, all directed to one or two points of course itself limited; but it was upon that, as which the tion, that Basil Valentine, Paracelsus, and Van Helmont commenced their superstructure. These writers, of whom we are in various ways indebted, were employed in making the processes which they employed from the Alchemists, subservient to the preparation of active medicines chiefly drawn from the minerals for there dom: while, at the same time, they had the difficulty of combating the established usages of the medical sects, how- but less efficacious, preparations of the Galenic system of Physic.

While thus Medicine adopted Chemistry as its absolute date auxiliary, Philosophy claimed its aid as an antiphilosophical interrogating nature. On this ground we name so deserving of attention, as that of Francis Bacon, *Lord Verulam*. This extraordinary man, whose name bears the deepest stamp of originality and genius, pointed out to all the world the just paths to be pursued, Scientific investigation: nay, more, he set himself, and by himself walking in those paths not unprofitably, making Science his relaxation from the cares of the state, it afterwards became his solace in years of old age and affliction.

In the subsequent part of this introduction we will show name two or three of the great changes which the more creeds have hitherto undergone; but the new work will by no means admit of that full detail, which it (the rical detail, which we could with pleasure furnish in vain. We have said more of the Alchemists than of his con- say of the Chemists, because we feel that we are furnished from from them for ever: but it may be possible to furnish from knowledge our obligations to the Alchemists, and divested, they briefly, when each substance, which they brought to light or investigated, shall be in review before us.

*Basil Valentine* describes the fusion and acidification, obtaining nitric or sulphuric acid, as an essential in both *Triumphalis Antimonii* he explains that fire was known in the and properties of numerous metals, and the increase of weight their fusion and calcination.

*Paracelsus* was a bold and original writer of the XVIIth century; that his writings do not seem to be of great importance is concerned in the

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ment of Chemistry, as to the defence of the active  
Articles recently introduced into the *Materia*  
such as calomel and the antimonial prepara-  
He sank at an early age under the consequences  
of irregularity, and is buried at Saltzburg.

*Helmont*, a Physician of Brussels, succeeded to  
knowledge, and supported the credit of the medi-  
the two last named authors. His writings  
to us a favourable impression of a mind  
searching for Truth; but his energies are  
more towards Medicine than to pure Chemis-  
He first used the term *Gas* to designate all  
substances, atmospheric air excepted.

*Kell* wrote on Glass-making, and he also dis-  
the method of obtaining Phosphorus, having,  
had some shown to him by *Brandt*, a Che-  
of *Hamburg*, its first discoverer, who concealed  
its process from *Kunkell*, though he revealed it to  
*Jchem* Dresden.

one of *Amsterdam* was an experimentalist of  
the excellence; he wrote much, but he also  
much, and introduced many valuable improve-  
into the manipulations and apparatus of Chem-  
ame; he

He introduced the process for obtaining  
acid, and described the method of separating  
a from bones; he formed also the salts of that  
His discovery of the product of vinegar by the  
on of wood in close vessels, has not, until very  
obtained the attention it deserved, though now  
an important branch of our Manufactures.

formation and incorporation of the Royal  
in 1662, by *Charles II.*, together with a  
Institution, the French Royal Academy of  
formed in 1666 by *Louis XIV.*, were great  
measures, which, though at first they may  
to have owed their origin to the calls and  
Science, in the end acquitted themselves  
obligation by ennobling its purposes, con-  
its energies, and enrolling among its  
the most learned and dignified characters of

Royal Society originated at Oxford, but its  
removed their sittings from that place to  
for the sake of greater assistance and more  
utility. Among its earliest members was  
curable *Robert Boyle*, a most amiable man, a  
philosopher, and a sound Christian. He wrote  
ished much, and with good effect, though  
of genius does not seem to have been his  
Metic.

He was the contemporary of Boyle, of a dis-  
less amiable, but of genius more acute.  
He satisfactorily demonstrated the neces-  
sary of atmospheric air to the process of combustion  
which Hooke entertained were sub-  
ported with great ability by *Mayow*.  
Boyle, Hooke, and Mayow, upon the  
action, though, as we now believe,  
the *Herm* of the two, seem to have given  
disuse, doctrines advanced by *Beccher* and  
acquainted

imbibed from  
investigation, list of great and deserved repu-  
of undigested author of what is termed the  
foundations of combustion. In this theory  
an element of extreme subtilty,  
stitution of natural constituent part of some bodies,  
based upon the of fire whenever its par-

ticles are so liberated as to assume a violent vibratory  
motion that is natural to them. Every substance that  
it was possible to burn was supposed to contain *Phlo-*  
*giston*, and every substance when it had been burned  
was thought to have parted with its *Phlogiston*. This  
continued to be the general belief for more than half a  
century, though the reasoning of *Boyle*, *Hooke*, and  
*Mayow*, together with the experiments of *Rey*, show-  
ing that metals did not lose but gained in weight by  
combustion, were decidedly opposed to such an hypo-  
thesis.

*Hooke* recognised the combination of oxygen in  
nitre, though that term was not applied to it till long  
afterwards. *Mayow* called it the *Nitro-aërial* sub-  
stance, and demonstrated its necessity to animal respi-  
ration. He also obtained hydrogen by the action of  
iron upon diluted sulphuric acid. His examination of  
the mutual actions of saline bodies is, perhaps, the first  
germ of the doctrines of analysis depending on compo-  
sition and decomposition. The sulphurets, both metal-  
lic and alkaline, are ably treated of in his works, and  
much of that system which is so forcibly sketched in  
the small portion of *Newton's* writings that is devoted  
to Chemistry, may be traced to the experiments, if not  
to the views, of *Mayow*. The whole of the doctrine of  
Chemical Attraction underwent great changes and im-  
provements subsequently in the hands of *Geoffroy*,  
*Bergman*, *Berthollet*, *Pfaff*, *Proust*, *Wenzel*, *Richter*,  
*Higgins*, *Dalton*, *Wollaston*, *Gay Lussac*, and *Proust*.

Although, in the divisions of Science to which we  
adhere, Heat does not form a part of Chemistry, yet  
as the Chemists of the period we are examining in-  
variably united these branches, we must now men-  
tion the discovery of the thermometer, an event which  
produced a decided and beneficial influence upon the  
progress of Chemistry in general. In regard to  
priority of claim to this valuable invention, authors are  
divided between *Drebbel*, of Amsterdam, and *San-*  
*torio*, of Padua: both lived in the latter half of the  
XVIIth century. The Florentine Academicians, how-  
ever, were the first to reduce the instrument to pur-  
poses of practical utility. But all their instruments  
wanted the essential of comparability. It seems  
doubtful; but *Dr. Halley* is said to have introduced as  
one fixed point of comparison, the boiling point of  
water, and *Newton* certainly made use of both this  
and the freezing point of water: thus obtaining two  
fixed points universally attainable, and rendering all  
thermometric indications comparable with each other.  
*Van Swinden*, *Fahrenheit*, *Martini*, *De Luc*, *Saussure*,  
*Siz*, and *Leslie*, have published further illustrations, or  
have suggested improvements in this instrument.

To *Dr. Hales*, the author of the *Statistical Essays*,  
we must award the praise of having been the chief  
author of Pneumatic Chemistry, though it in some  
degree commenced with *Mayow* and *Hooke*. He  
refused high preferment in order that he might con-  
tinue his Philosophical pursuits, which served for his  
amusement amidst the zealous discharge of parochial  
duty, a course which only closed with his life in 1761,  
at 84 years of age. His experiments on the gases were  
very numerous and of a miscellaneous character; but  
those in which he applied the same industry to inves-  
tigate the respiration and chemical agency of plants  
are better directed, and still form an important portion  
of our knowledge in this branch of vegetable organiza-  
tion. *Herman Boerhaave*, of Leyden, was about

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**Chemistry.** contemporary with Hales. He was a distinguished Physician, a good Chemist, and an excellent man. His life by Johnson is well known, and justly admired.

**Black.** Dr. Black was Professor of Chemistry at Edinburgh. In Chemistry, his great discovery was that of carbonic acid gas, which he obtained from decomposing the alkaline and earthy carbonates. But even this, great as it was, was exceeded, in originality and beauty, by the grand addition which he made to Physics of the knowledge of *Latent Heat*, about the year 1760. (Vide *HEAT*, Art. 249.) The practical importance of this doctrine was readily seen and employed by the vast mechanical genius of Watts.

**Bergman.** Following a sort of chronological order, the name of Bergman next occurs. He was of Upsala, in Sweden, and may be considered, in some sense, the earliest regular analyst whose name occurs in the History of Chemistry. His labours tended to the acquirement of a more intimate acquaintance with the properties of substances for the purpose of their separation, and also to those metallurgic processes so important to his country in particular. He died at the early age of 49, a martyr to his assiduity in the cause of Science.

**Cavendish, Priestley, Scheele.** The Honourable Henry Cavendish, Dr. Priestley, a native of Yorkshire, and Carl Wilhelm Scheele, a Swede, are names which may now be referred to, principally in connection with Pneumatic Chemistry. Priestley commenced by repeating the experiments of Hooke, Mayow, and Hales, on gaseous bodies, and he very greatly improved upon the apparatus formerly employed for these researches, leaving it much the same as employed at the present day. He is considered as having discovered oxygen gas on the 1st of August, 1771, when he obtained by concentrating the Sun's rays upon red precipitate over mercury. He named his new gas *dephlogisticated air*, though, in fact, it was the same which had been obtained from nitre by Hooke and Mayow. He diligently traced the functions of this air in the processes of animal and vegetable respiration. Mr. Cavendish discovered muriatic acid gas, and Priestley further investigated its properties. The latter also separated ammoniacal gas from the muriate by the action of lime: and discovered that which is now called sulphurous acid gas; examining also the properties of nitrous gas, which had been imperfectly known to Mayow.

The more prominent facts which were brought to light by the high talents of Mr. Cavendish, most assiduously, yet cautiously exerted, were the complete knowledge of hydrogen gas, which, though the substance had been obtained before, was quite disregarded until his time. These researches led him to the brilliant discovery of the composition of water, which he laid before the Royal Society in 1784. (Vide *ELECTRICITY*, Art. 167.) Thus was the synthesis of water accomplished.

The merits of Scheele were discovered and brought to light by Bergman, who wrote the Introduction to the first work of the former, *Chemical Experiments and Observations on Air and Fire*. It seems that Scheele discovered, independently of Priestley, many of the important phenomena made known by the latter about the same time. His observations on the radiation of Heat are highly interesting; but the discovery of chlorine (or Dephlogisticated Marine Acid, as he called it) must be considered his noblest achievement. This took place during his excellent examination of man-

ganese. He also commenced the genuine Chemical examination of the vegetable acids. Lastly, the discovery on Prussian Blue must be mentioned with high commendation. He died at the early age of 44.

We have now arrived at the era of Lavoisier, which produced another great revolution in the Chemical theory of combustion. The admirable Philosopher, whose name we have just cited, may be considered as the chief opponent to the doctrine of phlogiston as introduced by Stahl. That there existed no such body as phlogiston was asserted by Lavoisier, chiefly on the ground that substances which had undergone combustion weighed more than they had originally done; which they ought not to do if they had parted with some element previously combined. This operation was traced to the union of oxygen with the combustible body. The last and the ablest of the supporters of phlogiston was Mr. Kirwan, a distinguished native of Ireland. He published a small work in defence of his views. This work was answered by Lavoisier, and his associates Berthollet, Monge, Fourcroy, and De Morveau, who, having taken Kirwan's work, republished it with their arguments and experiments, attacking each chapter separately. Never was there a contest more purely conducted towards the investigation of truth; and never one in which the erroneous combatant gained for himself, by his candour, the admiration of impartial judges more completely than Mr. Kirwan. From that day phlogiston has disappeared from all Chemical writings. It seems to us most extraordinary that a belief in it ever should have prevailed to the extent that it did: for there were abundance of facts and experiments which ought to have overturned it long before. These facts, however, Lavoisier has the merit of having systematized and brought to bear upon the question. But here we stop, and do not concede to him the merit of absolute originality in those experiments by which the antiphlogistic doctrines were supported. On this subject we fully agree with Mr. Brande, in the following observations taken from the Historical Introduction prefixed to his *Chemistry*, published in 1821.

"It requires no deep inquiry, or minute investigation, to detect in the researches of Priestley, Scheele, and Cavendish, the materials of which their contemporary, Lavoisier, aided by several celebrated Chemists of the French School, constructed his new theory; and a retrospect of the works of Mayow and Hooke will show that the antiphlogistic system almost necessarily arose out of a combination of their views with the more modern discoveries."—p. 172.

"If we look to the abstract facts on which it (the antiphlogistic theory) rests, we shall search in vain, either in the works of Lavoisier, or in those of his contemporaries; they were exclusively furnished from other quarters; and, without any undue prejudice, of which indeed Science should always stand divested, they will I think chiefly be found in the writings of Mayow and Hooke, and in those of Priestley and Scheele. The prominent features of the French theory are its explanation of the theory of combustion and acidification, the presence of oxygen being deemed essential in both cases. That air is the food of fire was known in the remotest Ages; that it causes the increase of weight sustained by metals during their fusion and calcination, was shown by Rey early in the XVIIIth century; that a part only of the atmosphere is concerned in the



**Chemistry.** support of flame, was explained by Hooke in 1667; and the vital or igneous spirit (as he terms it) of the atmosphere, is concerned in the formation of acids, was asserted by Mayow in 1674. Here, without advancing into the XVIIIth century, we have in explicit detail, all the facts and arguments requisite for the construction of the French theory; but if to these we add the discovery of oxygen by Priestley, and of the composition of water by Cavendish, what then becomes of its claims to originality?"—p. 182.

The name and talents of Lavoisier did much for the introduction of the new system of Chemical nomenclature. From considering it the principle of acidification, he gave its present name to oxygen gas; azote, hydrogen, and carbonic acid gas, are also terms of the same era.

Lavoisier's principal discovery, was the actual combustibility of the diamond, which had before been suspected by Newton; showing also its Chemical identity with common charcoal.

For the last and greatest advancement in Chemistry, we are indebted to the aid of Electricity. Dr. Priestley is, perhaps, the first who thus called in the powers of a sister Science. At least he seems first to have noticed and examined an experiment of Warltires, tending towards the synthesis of water by firing a mixture of oxygen and hydrogen gases. Mr. Cavendish pursued these researches, and was thus the first to demonstrate the composition of water. This was in the year 1781; and in 1789, the associated Dutch Chemists, Puits, Van Troostwyck, and Dieman, effected its decomposition by a varied application of the same agent. It is not, however, to ordinary Electricity that Chemistry is indebted for its greatest advancement, but to that species of action which arises from the Voltaic pile.

**Volta**

In repeating Galvani's experiment upon what he called the Animal Electricity, made by placing some zinc in contact with the nerve, and some copper in contact with the muscle of a recently killed frog, and then forming a contact between the two metals, by which a muscular convulsion was produced, Volta was led, about the year 1791, to the discovery of that beautiful series of mutual electric actions between the metals and other substances, which has subsequently borne his name. Mr. Cruickshanks improved the construction of the pile by converting it into a trough; and in 1800, Messrs. Nicholson and Carlisle may be said to have first witnessed the Chemical action of the pile in a most important instance, namely, the decomposition of water. In 1803, Hisinger and Berzelius greatly extended the knowledge of Electro-chemical agencies, by publishing a beautiful series of experiments, developing the law that "oxygen and acids are accumulated round the positive pole of the battery, while hydrogen, alkalis, earths, and metals are accumulated round the negative pole."

**Davy.**

The *Philosophical Transactions* for 1807 contains Sir Humphrey Davy's Paper, in which the Chemical agencies of Electricity are still further developed; and the brilliant experiment of the decomposition of the alkalis, with considerable evidence of the real nature of the alkaline earths, is described in one of the most interesting Memoirs ever presented to Science.

From this period the History of Chemistry does not present any very marked features to arrest our attention. It has continued steadily to advance, but without making any of those gigantic strides which we have

felt it necessary thus briefly to mention. Analysis of all kinds has been in a state of successive improvement. In France, this most important branch of the Science has been most successfully directed to the examination of the vegetable contents of the *Materia Medica*, with a view to practical purposes: while, at the same time, Dr. Prout in England, and Professor Berzelius in Sweden, have laid the foundations of noble researches in the Chemical physiology of animal bodies: from which ultimately the healing Art will unquestionably derive signal advantages.

In concluding this most circumscribed outline of the History of Chemistry, we may perhaps be allowed to express a faint shade of regret, which nevertheless has frequently passed over our minds within the space of the last five or six years. Admiring, as we most sincerely acknowledge that we do, the Electro-magnetic discoveries of Professor Oersted and his followers, we still as Chemists fear that our Science has suffered some degree of neglect in consequence of them. At least, we remark that during this period good Chemical analyses and researches have, with a few exceptions, been rare in England; and yet it must be confessed there is an ample field for Chemical discovery. How scanty is our knowledge of the suspected Fluorine! Are we sure that we understand the nature of Nitrogen? And yet these are among our elements. Much has been done by Wollaston, Berzelius, Gay Lussac, Thenard, Thomson, Prout, and others, with regard to the doctrine of *Definite Proportions*, but there yet remains the ATOMIC THEORY. Is it a representation of the laws of nature, or is it not? This is a point of vital importance to Chemistry: it yet remains undetermined. Let the Chemist and the Mathematician (for both are required) unite their powers for the solution of this problem.

For the History of Chemistry the reader may consult Borrichius, *de ortu et progressu Chemiæ*, 4to. (reprinted in Mangetus); Bergmån, *de primordiis Chemiæ*, Opuscula, vol. ii. or Upsal, 1779. Du Fresnoy, *Histoire de la Philosophie Hermétique*, 3 tom. 18mo. Paris, 1742; Boerhaave, *Elementa Chemiæ*, Lugd. Bat. 1732; Gmelin, *Geschichte der Chemie*, Göttingen, 1797, 3 vols. 8vo.; Fourcroy, *Discours Préliminaire* to his System, in 6 vols. 4to.; Brande, *Historical Introduction* to his Chemistry, in 3 vols. 8vo. Lond. 1821.

For the Alchemists, P. Borellus; also a catalogue of English Alchemical Authors in the translation of Helvetius's *Golden Calf*; Mangeti *Bibliotheca Chemica*, 2 tom. fol. Geneva, 1702, contains a copious assemblage of Alchemical writings; *Theatrum Chemicum* (per Laz. Zetznerum) Argentor., 6 tom. 8vo. 1659; Elias Ashmole, *Theatrum Chemicum Britannicum*, fol. 1652; *Lives of the Alchemists*, (Barret,) London, 8vo. 1815.

We subjoin a chronological list, which will be found convenient, as giving the date of the birth and death of the Chemists mentioned in this introduction. It does not contain the Alchemists, as these have been already noticed.

	Born.	Died.
Basil Valentine .....	publ. 1604	
Paracelsus .....	1493	1541
Cardan .....	1501	1576
Van Helmont .....	1557	1644
Libavius .....	1558	1616
Francis Bacon .....	1560	1626

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	Born.	Died.
Sanctorius .....	1561	1636
Crollius .....	publ. 1609	
Key .....	publ. 1630	
Kepler .....	1571	1630
Glauber .....	publ. 1651	
Guericke .....	1602	1656
Ashmole .....	1617	1692
Beccher .....	1625	1685
Galileo .....	1564	1644
Torricelli .....	1608	1647
Boyle .....	1627	1691
Kunkell .....	1630	1703
Hooke .....	1635	1702
Lemery .....	1645	1715
Lemery, jun. ....	1677	1743
Newton .....	1642	1727
Mayowe .....	1645	1697
Homborg .....	1652	1715
Halley .....	1656	1741
Brandt .....	1458	1521
Stahl .....	1660	1734
Hoffman .....	660	1742
Boerhaave .....	668	1738
Hales .....	1677	1761
Fahrenheit .....	1686	1736
Geoffroy .....	1672	1731
Margraaf .....	1709	1782
Ward .....		
Roebuck .....	1718	1797
Brownrigg .....	1711	1800
Macquer .....	1718	1784
Mayer .....	1723	1762
Macbride .....	1726	1778
Irvine .....	publ. 1769	
Black .....	1728	1799
Fontana .....	1729	1805
Cavendish .....	1731	1810
Priestley .....	1733	1804
Bergman .....	1735	1784
Watt .....	1735	1819
Rutherford .....	1695	1779
Kirwan .....	publ. 1789	
Wilcke .....	publ. 1782	
Morveau .....	1737	1815
Crawford .....		1795
Irvine .....	publ. 1805	
Scheele .....	1742	1786
Lavoisier .....	1743	1794
Foycroy .....	1755	1809
Pfaff .....	publ. 1792	
Wenzele .....	publ. 1782	
Richter .....	publ. 1792	

## CHEMICAL APPARATUS.

Before any attempt is made to explain the principles of the Science, it may be advisable to describe the Instruments employed in Chemical researches.

*The Laboratory* is the building or room wherein the Chemist carries on his operations. In describing such a building with its requisite furniture, it is intended to mention, as far as our limits will allow, all that is necessary for an ample range of Chemical research: but lest the extent of the apparatus should appear a formidable obstacle to the commencement of this fascinating and important study, it must be premised that we are

about to describe more than it may be in the power of every person to command. It will be said, however, for any one to select whatever instruments are essential to that particular branch of the Science which he may design to investigate. From the very great improvements which the last twenty years have produced, the cumbrous vessels and tedious processes of the early Chemists have given place to simpler and more delicate modes of experimenting. Formerly, the instruments of the experimentalist and the manufacturer were identical; to the latter they remain the same, as quantity is his object, but in the present improved state of Chemistry, the blast-furnace and the evaporating pan have in most instances given way to the blowpipe and the watch-glass. It is true, that in a well-appointed Laboratory they are still essential, but the command of a spare room and a small stock of instruments will enable any person to verify processes, and even to prosecute new objects of research with little cost or inconvenience.

It scarcely need be remarked, that in a Science depending so much on manipulation, and the habit of accurate observation, a little practice will teach more than volumes of reading. Numerous minutiae, too unimportant and tedious for description, may easily be gained by experience, or by the aid of a skilful instructor. A Work, however, expressly devoted to this branch of the subject, has been recently published by Mr. Faraday, of the Royal Institution; it will be found ample in its details, and invaluable to any one entering upon Chemical studies.

Perhaps, on the whole, the most advantageous form for a Laboratory, would be that which allowed of one ground-floor room, a cellar beneath, and a chamber above. The cellar serves as a convenient store-room for glass and earthen vessels not constantly in use, carboys of acids, and other things that require to be kept in large quantities; but the main object of this arrangement, is to keep the ground-floor room free from dampness, which is extremely injurious to the furnaces and to all iron work, detaches the labels from bottles, and dissolves the deliquescent salts in the moisture they imbibe. On the ground floor, a space of at least six feet in width along one side should be appropriated to the range of furnaces, and under this part the cellar ought not to extend, as no floor could support the weight without arches, and no wood ought to enter into its structure. The floor of this part should be brick or stone, but the remaining part of the room may have a boarded floor. Over the whole of this fire-proof space, a chimney should extend, and may taper upwards, so as to become of the ordinary size at the top of the building. If the front of this chimney be supported by pillars or arches, the height should everywhere be sufficient for a person to walk freely under without stooping. The main object of this capacious chimney, is for the purpose of allowing all acid fumes and noxious gases to escape without being diffused throughout the air of the room.

Under this open chimney, the flues from all furnaces may be made to terminate. In the arrangement of these furnaces, convenience must principally be studied; and for their construction individually, we refer to the descriptions hereafter inserted. It is desirable so to arrange, that as some one fire must always be kept in the Laboratory, that one should heat a sand bath, in which evaporations may be going on simultaneously with other operations. Of all the



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neces so contrived, the one now in use in the Laboratory of the Royal Institution, standing quite free from any wall, seems the most simple and useful. Its construction may be seen in p. 90 of Mr. Faraday's Work.

We now proceed to describe the furniture of the Laboratory in alphabetical order, for the convenience of reference.

**Air-pump.** For a description of this instrument, see PNEUMATICS.

**Alambic.** See *Distillatory Apparatus*.

**Balance.** For the particular description of this most important instrument, with a review of those mechanical and statical considerations which influence its construction, we refer to the word BALANCE, in the *Miscellaneous Division* of our Work. A well-furnished Laboratory ought to contain three Balances, at least; the largest, capable of weighing several pounds; a middle size, for weights from a thousand grains to about one pound; and, lastly, a very delicate beam for the purposes of accurate analysis. Some Balances have been constructed so as to possess great sensibility, even when bearing a considerable weight in each scale, but such are very expensive. The Royal Society is in possession of a remarkably fine instrument of this description, made by Ramsden. (*Jour. de Phys.* xxxiii. p. 144.) The scales in common use will turn with  $\frac{1}{10}$  of a grain, and may be loaded with 1000 grains in each pan, without materially diminishing the sensibility. The beam ought to be made of some metal which will resist the acid fumes of the laboratory; and for this purpose platinum has been sometimes employed, but it is expensive, and rather liable to permanent derangement of form. Bell-metal has recently been suggested, as, although it is flexible, the form is restored by its elasticity. The pans, and even the lines by which they are suspended from the beam, should be of platinum. The instrument ought always to rest under the protection of a glass case. The weights also should be of platinum, as not being liable to oxidation or corrosion, and admitting a ready purification from grease and dirt by exposing them to a red heat.

**Balloon.** A large glass globe used as a receiver, having a short neck adapted to the reception of the beak of a retort. See Plates, CHEMISTRY, fig. 1.

**Barometer.** A general description of this instrument will be found in PNEUMATICS and BAROMETER.

In the Laboratory it is essential to ascertain the atmospheric pressure during any quantitative experiment on a gas; as, without such observation, we cannot know the real mass of any compressible fluid confined in a vessel of given capacity. There is, however, another important consideration attendant upon this problem; for, supposing both the volume of the gas, and the atmospheric pressure, the same in two cases, yet if the temperatures differ, it is obvious that owing to the very great change which heat produces in the elastic force of gaseous bodies, the quantities in the two cases will not be the same.

All experiments, therefore, are referred to a standard pressure and temperature; and as they are necessarily made under great variety of circumstances, it becomes necessary to reduce the results, when so obtained, to what they would have been, had the standard pressure and temperature existed. The rules for this calculation will be given in a subsequent part of this Paper, in describing the Physical Properties of Gases.

**Bladders** are frequently employed for the transfer of gases. Those of the calf and ox are preferred; stop-cocks are fastened to the neck so as to make them airtight, and they are then fit for use. It has been attempted to cover them with a coat of oil-paint; this, however, soon cracks and peels off. Perhaps a delicate varnish holding caoutchouc in solution might be advantageously adopted. Bags of fine silk thus varnished have been sometimes substituted for bladders.

**Blowpipe.** For an ample description of this instrument, which belongs not to Chemistry only, see the word in the *Miscellaneous Division* of this Work.

**Capsule.** A small evaporating dish.

**Crucibles** are vessels for containing substances that are to be exposed to very violent degrees of heat. They are made of various forms, figs. 3, 4, 5, 6, and 7. Some have lids, and some have not. The materials of which they are made are various, according to the purposes for which they are designed. Platinum renders on this occasion essential assistance to the Chemist from its infusibility in all furnaces, but it does not well withstand the continued action of alkalis, and, still less, that of one genus of salts, the nitrates; and, if exposed without protection in a common coal fire, the vessel is frequently rendered brittle, and spoiled by the arsenic and sulphur which is found in some varieties of coal. Pure silver Crucibles are extensively used in the analysis of minerals, as they resist the action of alkalis; and though they are unable to bear more than a low red heat, yet that is amply sufficient for the analyst's purpose. Indeed it would appear, that even if the Crucible would bear it, little is to be gained by a greater elevation of temperature. In all cases, if possible, it is better that the platinum, or silver Crucible, be imbedded in sand within a common earthen one: thus the heat is more gradually applied, and the crucible is protected from the immediate action of the fire. Crucibles are also made of iron, but such are seldom used by the experimental Chemist. A very delicate and cleanly sort of Crucible is made of porcelain or Wedgwood ware, but these are extremely liable to crack, if either heated or cooled without great caution.

In using platinum Crucibles care should be taken to avoid those substances from which Chlorine may be disengaged. Also not to fuse nitre, nor either of the caustic fixed alkalis in them, for, in this case, a protoxide of platinum is formed and dissolved in the salt. Not to calcine in them such bodies as may leave a metallic residuum, such as the metallic salts from vegetable acids, nor mixtures which may produce phosphorus. When such metallic oxides are calcined as have but feeble affinity for oxygen, (as lead, bismuth, copper, cobalt, nickel, antimony, &c.) the temperature must never be raised above a moderate redness; for although these oxides are not decomposable *per se*, their reduction may take place at a high temperature, in consequence of the affinity of their metals for platinum. In long continued calcinations, the Crucibles must be protected as much as possible from the immediate contact of the fuel; for the metal is very apt to receive injury from substances accidentally met with, though in small quantities in the coke or coal, as we have already remarked; and even when these are the purest, silicon is present, which in the course of time unites with and injures the Crucible, by rendering it brittle.

For enduring a violent furnace heat, the common Hessian Crucibles, made of clay and sand, are to be

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**Chemistry.** preferred; the Cornish Crucibles also are excellent; they are, of course, slightly acted upon by alkaline fluxes and vitrified oxides, but are, on the whole, the best for metallic reductions. In some cases, to prevent the adhesion of the metal to the bottom of the Crucible, it is advisable to smoke the inside well over a lamp, or even to line the interior of the Crucible with pounded charcoal, made into a paste with a small quantity of linseed meal and water. The black-lead Crucibles are made of that mineral and fine clay: they bear the most violent heats, and are little disposed to crack, but they are quite unfit for retaining fluxes. Their principal use is for the fusion of metals; and the larger kinds are easily converted into most convenient portable furnaces.

**Distillatory Apparatus.** The process of distillation depends upon this principle, that by the application of heat many liquids, and even solids, may be raised in the state of vapour, and again condensed when that vapour arrives in such a situation as to lose the heat which had been communicated to it. Thus a separation of pure from impure is effected. For instance, in the Laboratory it is essential to have a copious supply of pure water. Now the common spring water is usually contaminated with earthy and alkaline salts, and with some mineral acids. To remove these, distillation is resorted to. Fig. 8 represents a common Laboratory still. This instrument frequently forms a part of the range of furnaces underneath the open chimney, but it may with equal or greater convenience be placed over a portable furnace, as in the Plate, and in this form its construction will be more obvious. A is the body of the furnace, B its door. C the top, or lid of the furnace, is removed; and in its place is the body of the still fitting in like a pan to come over the fire. H is the head of the still fitting well to the body, and continued by a long neck D, which enters the worm tube at F. E is the refrigeratory, a wooden vessel, filled with cold water, through which the worm tube passes and issues at G. Suppose the body of the still filled with pump water, and placed over the furnace; as soon as ebullition commences, the steam will proceed towards G, its only outlet: but in its passage thither, being condensed by the cold water surrounding the worm, it will issue in a small stream from the orifice G.

By the early writers the term *alembic* was given to instruments for distillation, and is still employed by some. Fig. 9 is a representation of a very convenient form, in which the necessity for a worm tube is avoided; and it may be used either for distillation over the fire immediately, or with the intervention of a water-bath. It consists of four pieces; A is the boiler which fits into the top of a portable furnace, as far as the projecting shoulder A. At E is an opening closed by a cork, through which additional supplies of the liquor to be distilled may be introduced without disturbing the apparatus. B is the water-bath, which sinks almost to the bottom of the vessel A, and is thus deeply immersed in the hot water. This part is only occasionally fitted in to distil such spirituous liquors as do not require the greater heat of the fire, and, in fact, would be injured by unprotected exposure to its action. C is the capital, or part in which the vapour is condensed; the form is conical, and a small channel runs round the bottom internally to collect the condensed fluid as it trickles down from the under surface of the cone. From this channel it is conveyed into any convenient vessel by a

pipe terminating at F. The upper surface of the cone forms the bottom of the vessel D, which is kept constantly full of cold water for the condensation of the vapour, and hence is called the refrigeratory. This water is let off by the stopcock e, when it becomes warm, and a fresh supply is poured in at the top, which is left uncovered for the purpose. The whole may be made of tinned copper; and this alembic possesses a great advantage over the still before described, that all its parts may readily be cleaned; while, if the still with the spiral worm be employed for strongly-scented waters, or volatile oils, it is extremely difficult to get it free from their contamination. Some trouble is caused by the necessity of frequently changing the water in the refrigeratory; and it is essential that the cone be made to taper upwards to a considerable height, as otherwise the drops are apt to fall back into the boiler, or body of the still. This form of the instrument is, probably, more ancient than the spiral condensing worm, as it is only an improvement upon the simple alembic of the Alchemists.

Fig. 10 represents this last-mentioned instrument. It consists of two parts, the cucurbit A, into which the substance for distillation is put; and B, the capital, or part wherein the vapour is condensed; the neck C of the cucurbit fits into the capital and round the rim of the latter at DD: there is a channel in which the liquor from the top of the capital is collected and carried by a pipe E into the vessel destined for its reception. Sometimes the whole is of one piece, and in this case there is a stopper at F for the admission of the liquor to be acted upon. Silver or glass are the materials of which this instrument is usually formed, and it may be conveniently used over a lamp, or in a sand-bath. The bottom of the cucurbit, if made thin, will bear a considerable heat.

The most simple, and, for Chemical purposes, the most common, apparatus for distillation, is the *retort* and *receiver*.

The *retort* is either plain (fig. 11) or tubulated, (fig. 13,) and fitted with a ground stopper at the top. A is the body for the reception of the substance, B is the neck, and C the beak which is fitted into the neck of the receiver. (fig. 12.) In some cases, also, luting is applied to keep the vapours enclosed within the vessels. Retorts are made of different substances; as lead, porcelain, earthenware, and glass; the latter may conveniently be used over an Argand's lamp; and will, if good, bear any heat below that at which glass fuses.

When the plain retort is used, a long funnel, (fig. 15,) called a *retort funnel*, is extremely convenient for pouring in a liquid without wetting the neck of the retort.

The *receiver* (fig. 12) is the vessel into which the distilled liquid drops from the beak of the retort; and in some cases to effect the entire condensation of the vapour, it is necessary to keep the receiver immersed in cold water, or even in a freezing mixture.

The *adopter* (fig. 14) is employed to prolong the distance between the retort and receiver. The beak of the retort is inserted at one end, and the beak, or small end of the adopter, in a similar manner, enters the mouth of the receiver. These vessels are usually made of glass.

Fig. 16 represents a very convenient little retort easily made from a piece of glass tube, and which may, if necessary, be called the *tube retort*.

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**Dropping Bottle.** A common bottle of any sort with a tube passing through the cork, having a capillary orifice. This is a most useful little instrument; as it is obvious, that if the bottle be half full of distilled water, and held in the hand when inverted, the expansion of the air from the warmth of the hand will propel the liquid, drop by drop, from the orifice of the tube. See fig. 17.

**Dropping Tube.** This is represented in fig. 18. It is useful to add gradually any liquid reagent to a solution; for the lower orifice being extremely small, the tube may be filled by sucking the air out from the larger end, and the finger applied to the orifice from which the mouth is removed, prevents the escape of the liquid from the tube, until it is brought to the vessel for which it is designed; and when there, regulates to a drop the quantity suffered to descend from the tube.

**Drying Instrument for Precipitates in Filtrés.** A (fig. 19) is an Argand lamp, B is a vessel containing water to be boiled by the lamp, with a sort of chimney by the side for the escape of steam. C is a glass vessel, which, resting on a rim, sinks into the water; and within this conical glass the filtre to be dried is placed.

**Eudiometer.** Of this instrument there are several kinds; the earliest was employed by Priestley, in consequence of his discovery that nitrous gas absorbed oxygen from atmospheric air, and produced a substance absorbable by water. This method will be described hereafter, but for the experiment itself a graduated glass tube is sufficient, with another smaller one of known capacity, by which to measure the quantities of the respective airs submitted to experiment. Fig. 20 represents Priestley's instrument.

**Volta's Eudiometer** consists of a very strong glass tube, about seven inches long, open at the lower end only, and graduated into hundredths of a cubic inch. (fig. 21.) Very near to the top of the tube a short piece of wire passes through, and is cemented into each side of the tube, leaving a distance of about  $\frac{1}{2}$  inch of an inch in the middle of the cavity of the tube between their two ends. When a mixture of gases, that may be united by the electric spark, is confined in this tube, one of the wires is connected by a chain with the outer coating of a charged jar; then if the glass knob be brought into contact with the other wire, a discharge takes place, causing a strong spark to pass between the ends of the wires within the tube, and thus the union of the gases is effected. The French close the lower end of this Eudiometer with a stopcock, and give a more complicated form to the whole instrument; but it is thereby rendered more liable to be burst by the violence of the explosion. In England the Eudiometer generally stands over the mercurial trough at the time of an experiment, and is supported by an iron clamp, which by means of a spring allows of some elevation at the moment of the explosion, but not so much as to raise the tube above the surface of the mercury. It is an advantage to be able to sink the Eudiometer down into the fluid, so that the exterior portion may be on a level with that on the interior of the tube, otherwise a calculation is necessary.

To these instruments we must recur hereafter when a greater knowledge of Chemical agents may make their use more intelligible. Fig. 22 is Dr. Hope's Eudiometer; fig. 23 is Mr. Pepy's; figs 24 and 25 Davy's;

and fig. 26 is a graduated glass tube as employed by Berthollet.

**Evaporating Dishes, or Caplets,** are generally made of Wedgwood's ware, either in the form of shallow pans, (fig. 27,) or segments of a sphere, (fig. 28;) for some purposes dishes of copper, platinum, or silver, may be employed; and for minute experiments a watch-glass is a most convenient vessel.

**Files.** Of these different sorts are required, but especially the three-cornered file for cutting a small notch in glass tubes, after which they easily break in the place required. Also the kind called Rat's-tail, as with these perforations are readily made in corks, through which glass tubes have to be passed.

**Filtre.** The process of filtration is so generally known as to render all description unnecessary. For some purposes a vessel made of porous stone is employed, or even a jar with a stratum of sand at the bottom. Hair sieves, flannel bags, and muslin, or a piece of tow in a common funnel. For all delicate purposes in the Laboratory a piece of unsized paper is preferable. If the filtre is large it must be folded into a conical form, and placed within a glass tunnel, but in all cases it is advisable to avoid the use of filtres as much as possible. The object of filtration is generally to obtain a precipitate, that it may be dried and its quantity ascertained; now it is scarcely possible to remove the whole of the filtered substance from the paper without loss; and if the precipitate be dried upon the filtre, unless the paper be reduced to exactly the same state of dryness as at first, a fallacious weight is introduced. In most cases a precipitate will in a reasonable time sink down to the bottom of a fluid with which it is mixed, and the clear supernatant liquid may be drawn off by a sucking tube, (fig. 18;) but as a paper filter is sometimes necessarily employed, the following artifices are not without their utility.

From the same sheet of paper make a double filtre, that is, one filtre fitting within another. Use both together, and dry both together. Then take the one containing the precipitate out of the other, and by placing the empty one in the scale which contains the weights, a counterpoise is obtained, and all further calculation rendered unnecessary.

Sometimes the precipitate is to be dried at a red heat; and although the ashes remaining after the combustion of a small filtre do not amount to more than  $\frac{1}{10}$ th of a grain, and might easily be allowed for, yet frequently the precipitate is of such a nature that the carbonaceous matter would at a high temperature produce decomposition. Perhaps in such a case the following method is as short as is consistent with accuracy.

Use the double filtre as before. Reduce the whole to such a state of dryness as may leave the precipitate state coherent, but not pasty. By separating the filtres, and using one as a counterpoise to the other, the weight of the precipitate in this state is known. Let this weight =  $a$ . Detach some of the precipitate from the filtre, and put it into a platinum crucible, carefully ascertaining the weight of the quantity so introduced. Let this =  $b$ . Subject the crucible and its contents to the required heat, and again ascertaining the weight of the precipitate now it is thoroughly dry, let this weight =  $m$ ; then it is evident from proportion that the weight of the whole precipitate, supposing it so dried, =  $\frac{a \cdot m}{b}$ .

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When the quantity of fluid to be filtered is very small, and the clear liquor is wanted for experiment, it is advisable to moisten the filtre first with distilled water, to compensate for the moisture which it will absorb.

**Flasks.** Figs. 29, 30, and 31 are of the common form and of white glass; they are principally used for forming solutions in acids, water, &c. The common flasks in which Florence oil is sold are the best that can be procured; they will bear a heat approaching to redness without injury, and always form a serviceable and cheap resource for the experimental Chemist.

**Furnace.** In the construction of furnaces there is great variety; the following, however, are some of the most useful, but in the processes of modern Chemistry large furnaces are much less called for than formerly.

**The Evaporating Furnace, or Sand-bath.** Fig. 32 represents a front section of the furnace; A, the ash-bin; B, the grate; C, part of the flue; E, the sand containing an evaporating dish at F; G, the place of the ascending flue. Fig. 33 represents a vertical section, perpendicular to the former. The other parts correspond; but it is to be observed, the flue C, after running along the front, returns again, and is carried along the back, as at D, before it rises to form the chimney G.

The **Blast Furnace** is variously made, but fig. 34 is on the whole the most convenient. "A is the internal cavity for containing the fuel and crucible, it is slightly bevelled downwards, as in the figure, to allow of the fuel sinking down as the lower part is consumed; B is the flue passing into a hot chamber; C, an appendage particularly useful for drying luted crucibles, or raising them gradually to a proper temperature for the furnace, for roasting ores, and various other purposes; D is the flue connecting it with the vertical chimney E, which, to produce a strong heat, should be 30 or 40 feet high; F F are covers, consisting of twelve-inch Welch tiles, with handles; G, the stoke-hole, through which no more of the fire is seen than what appears between the grate and the bearing bar H, this space is left for the purpose of raking the fire, or occasionally taking out the bars; K is the ash-pit, which is sunk below the level of the ground, and is covered, when it projects at L, by an iron grating." Henry.

**The Reverberatory Furnace.** "Figs. 35, 36, and 37 represent the section and plans of a Reverberatory Furnace. The fuel is contained in an anterior fire-place, and the substance to be exposed to the heat is placed on the floor of another chamber, situate between the front one and chimney. The flame of the fuel passes into the second compartment; by the form of which it is concentrated upon the exposed substance, which is never confined in a separate vessel or crucible, but placed on the floor of the furnace. When reduced to a state of fusion, the melted mass is allowed to flow out through the tap-hole at H. In all three figures, A represents the ash-pit; B, the grate composed of movable bars; C, the door at which the fuel is introduced; D, a door in the side of the chamber for the purpose of inspecting the process; E, the floor of the furnace, which descends and is gradually contracted towards the back part; F, another door, for introducing and stirring the materials; G, the back part of the furnace, immediately under the chimney; H, the tap-hole; I, the chimney." (Henry's Chemistry.)

The **Forge**, as used in every blacksmith's shop, gives

a very intense heat, and forms a valuable part of every well appointed Laboratory.

The **Assay Furnace** being applied to the purposes of that art only, and but seldom used in experimental research, we refer to the Article on that subject in the *Miscellaneous Department*.

**Knigh's Portable Furnace** is one of the most useful, as it may be applied to a great variety of purposes. It is made of sheet iron, and lined with fire clay. Fig. 35: A is an aperture, with a movable stopper for the neck of a retort in distillation; B is the door; C, another aperture, corresponding to one on the other side, for introducing a porcelain tube if necessary; D is the ash-bin, with a sliding register to regulate the draught.

**Aikin's Portable Blast Furnace** is formed from the common black-lead crucibles used by the goldsmiths. In fig. 39, the lower piece C is the bottom of one cut off so as to leave a cavity of about one inch in depth. The middle piece or fire-place A is formed from another, and a third is inverted, and placed upon the centre piece at B; a hole is cut for the escape of smoke; the pipe of a pair of double bellows is inserted at F, and from the cavity in the piece C the air passes through six gimlet holes to the fire; on a stand, resting in the bottom of the furnace, a crucible is placed, as seen at X. This furnace, if supplied by the steady action of a good pair of double bellows, produces a prodigious heat, and is certainly one of the most economical and effectual furnaces in the Laboratory. By a slight alteration it may be adapted to the purposes of assaying. See Henry's Chemistry, vol. i. p. 446.

**Common Crucible Furnace.** The same kind of crucible, with a small kind of grate loosely fitted in, so as to give room for a sort of ash-bin beneath, and having a hole, as at A, fig. 40, for the pipe of a pair of bellows, will be found of constant and essential service.

**Gasometer.** An instrument for containing gases, and, as the name implies, for measuring their volume. Of the common gasometer, fig. 41 represents the vertical section. A is a hollow cylinder of sheet-tin, entirely open at the bottom, and sliding freely up and down between the sides of the fixed cylinder B and the exterior of the gasometer C. D and E are stopcocks at the mouths of the tubes, which run down the sides of the vessel, and, uniting in the centre, reascend to F, thus forming a communication with the interior of the instrument. Water is poured in at the top, and, by inspection of the figure, it is obvious that the water will rise from the bottom P Q, until it reaches the level of the dotted line D E, filling only the space between the cylinder B and the exterior surface of the gasometer; a circular ring of about one inch in breadth. Thus, all communication between the gas in A and the atmospheric air is cut off. By opening either or both the stopcocks, D and E, and pressing down the cylinder A, the air is driven out, and by the same apertures any other air may be introduced. The volume of air contained is shown by the graduated line on the side of the movable cylinder. G, G are weights running on pulleys for counterpoise. F is a cavity, in which it is sometimes convenient to put solid substances capable of abstracting certain impurities from the gas contained in the vessel.

**Pepys's Gasometer, or Gasholder**, consists of a japanned iron or copper vessel, fig. 42. A is the part which contains the gas, and commonly holds six or eight gallons. B is a cistern for holding water, having two

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*Gasometer for producing a uniform Pressure.* The gasometer, fig. 43, is taken from Biot's *Physique*, and either the same, or one on a similar principle, will be found of great service in many experiments on the gases.

Let a vessel B be furnished with tubes and stopcocks at S, R, and o. Let there be a communication by the tube Z (having a stopcock at O) with the vessel A, having apertures at F and T, the former fitted with a stopper, and the latter having a tube open at both ends. This flat top is cemented to the vessel A. Now suppose the cock at O closed, and that the vessel A is filled with water through F, which is then closed with its stopper. If the cocks S and o be shut, and those at R and O be opened, the water, descending, will drive the air through the tube at T, and this current of air will issue with a uniform velocity; for, by a well known law, it will at all times be subject to the pressure of a column of water, extending no higher than the point H, wherever the surface of the water may be in the vessel A. Of course it must not descend below the point H. The extremity of the tube Z is made to bend upwards in the vessel B, to prevent the air rising through the descending fluid into the vessel A.

To fill this gasometer with any gas, let us suppose the common air all driven out through R, and the vessel B filled with water. Close O and R. Affix a bladder containing the gas to  $\pi$ , which tube descends to the bottom of the vessel at A. Open the cocks at S and o, and, as the gas enters the vessel B, the water will issue at the orifice  $\beta$ , till the cock S be closed. In this state the instrument is extremely convenient for burning combustible gases from jets fixed at R, for the cocks S and o being closed, by opening O a uniform current of gas is delivered as before. It will easily be seen that the gas may, if necessary, be transferred to one or more such vessels, as represented in the plate wherein the corresponding letters A, B, F, H, O, &c. represent the

same corresponding parts in the first description. This apparatus provides a convenient method for subjecting gases to intense cold or to great heat; for, if the communication be made between R and S, by the tube  $\lambda$ , this tube may be passed through a furnace or other convenient apparatus, and by the intervention of a third vessel B, or the removing the former one B, the gas may be passed through the tube as often as is required.

Fig. 44 is the outline of a similar apparatus, in which the gas is preserved from the contact of water by passing backwards and forwards through the tube  $\lambda$ , from bladders at its extremities. Here B is, at first, full of air. By the admission of water and opening the cock at R, a current of air is driven into C, which, compressing the bladder, propels the gas through the tube V V, into the other bladder. By a similar application of the gasometer B, the gas may be driven back again to C, and so on without limit.

The *Graduating Tube* is a taper glass tube, fig. 45, with a capillary orifice. Suppose that it is required to graduate a glass measure into cubic inches, or tenths, or hundredths. The weight of such a given volume of mercury is easily obtained by calculation; this quantity is then carefully weighed into a glass capsule, and from thence either poured or sucked into the tube. The height M, at which it stands in the tube, is then marked with a file, and by successively filling the tube to this mark, and then transferring the contents to the tube to be graduated, marking it at each time, any number of the required degrees may be obtained.

In this process let  $s$  be the specific gravity of the mercury employed, and as at the temperature  $62^{\circ}$  F., a cubic inch of water weighs 252.458 grains troy, it follows that if our graduation required were  $\frac{1}{100}$  of a cubic inch, we must take a weight of mercury equal to  $2.52458 \times s$  grains, to form the standard division upon our graduating tube.

*Jars.* Of these Pneumatic Chemistry will require an extensive assortment; they are of glass, and of different sizes; some are graduated, some are not: the method for graduating these, is identical with that employed for measures.

*Knives.* The common pallet knife of the painters, and other similar instruments made of horn or bone.

*Lamp.* The kinds employed in the Laboratory are the lamp in which spirit of wine is burned from a cotton wick, or from a wick made of a faggot of fine brass wire; figs. 46 and 47. The former is of glass, the latter of japanned tin. Fig. 48 represents Argand's Oil Lamp in its most common form. In this well known and excellent lamp the wick has a circular form, and thus allows a current of air to pass up through the centre of the flame. The combustion is rendered so perfect, by proper management, as to allow of no deposit of lamp black on the vessels exposed to its flame. For effecting solutions in flasks, for distillations in small retorts, and, indeed, for every experiment to be conducted on a small scale, this is an invaluable instrument in the hands of the experimental Chemist.

Professor Daubeney, of Oxford, speaks highly of a portable gas lamp, and such we have seen; but, as yet, this sort of lamp is not in general use.

*Lutes and Cements.* Lutes are cementing substances applied to the joints of Chemical apparatus, especially retorts and receivers, to prevent the escape of volatile matters. It is sometimes necessary to smear or coat the surfaces of retorts or tubes with some such substance,

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**Chemistry.** to protect them from the action of a strong fire. Cements are of essential service in the Laboratory to join broken vessels, and to assist in constructing the endless variety of apparatus employed in Chemical research. A few, therefore, of the most useful kinds of each will be described.

**Fat Lute** is made of good clay, of which, perhaps, that used by the pipe-makers is the best: it should be well dried, (but, according to Thenard, should not be calcined,) finely powdered, and sifted. It is then to be gradually mixed, and beaten up with drying oil. The more beating it receives, the better is its quality. The quantity of oil is to be such as to make the lute of the consistency of glazier's putty. It resists well the action of corrosive vapours, but, of course, does not bear much heat. In a closed earthenware vessel it will keep long uninjured, which greatly adds to its convenience.

**Linseed, or Almond Meal**, or any coarse farinaceous substance, if formed into a paste with water, or, what is still better, dissolved starch, or weak glue, will make an excellent lute: it should be bound round with slips of moistened bladder, or bits of rag. This is, perhaps, the most convenient lute of any, but its combustibility limits its application.

**Lime** forms the basis of some valuable lutes and cements. Let a lump of quick lime be partially slaked, by being once dipped in water, and then suffered to fall to powder: a thin paste formed of this with strong glue, or the white of eggs, is very tenacious, and sets with great rapidity, especially if some more of the powdered lime be strewed over it. For joining glass tubes, retorts, and receivers, and other such purposes, a rag may be dipped in the glue or white of egg, and wrapped round the vessel: the lime being applied afterwards.

Lime and fine brick-dust, formed into a paste with blood, will make a cement, having a considerable power of resisting moisture for coarse purposes.

A simple and excellent method for joining glass apparatus, is by soaking slips of bladder in warm water: the bladder then thickens, and if smeared with paste or white of egg, will closely adhere. Linen rag and paste may, sometimes, be similarly employed. The cements of lime have this advantage, that they may be applied instantly to any accidental crack: and thus, by careful management, the vexation and loss of beginning an operation anew is avoided. They bear also a considerable heat without injury.

**Fire Lute** is applied to retorts, or tubes, when it is necessary to subject them to a strong heat, by which they might otherwise fuse or fall together and lose their shape. It is prepared by beating clay with as much fine sand as can be employed, without destroying the tenacity of the mass: old crucibles pounded are better than the sand; and chopped hair, or straw, or tow, must be added in small quantity. Such a lute is applied to the interior of iron furnaces, to protect the metal from the action of the fire. The lids of crucibles are cemented on, when required, with this compound. One thing is important, that the coated vessel be suffered to dry thoroughly, before it is subjected to the action of the fire.

**Fusible Lute** is of service chiefly to counteract the porosity of earthen retorts, or to fill up the cracks by which they are too often impaired. The following is recommended for this purpose. (*Reperbury of Arts, &c.* vol. i.) "Dissolve one ounce of borax in half a pint of boiling water, and add as much slaked lime as will

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make it into a thin paste. Spread it over the retort with a brush, and, when dry, apply over the whole a lute of slaked lime and linseed oil, beaten till it is perfectly plastic. This becomes dry in a day or two, and the vessel is then fit for use. Stoneware retorts may thus be used several times with safety, (always renewing the oil and lime lute,) whereas, in the common way, and even with the clay and hair lute, they generally crack when cooling, or on being heated a second time."

The following composition is recommended by Aikin for joining on the covers of crucibles, or other such purposes, where it is required to keep the vessels air-tight when hot. "Brick-dust and clay, in fine powder, are to be mixed with a tenth part of glass of borax: when wanted for use, a sufficient quantity is to be mixed with water, so as to be conveniently applicable to the vessels. The heat to which they are afterwards exposed, brings the luting to a state of semivitrification adhering firmly to the crucible."

**Parker's Cement**, made into a paste with water, soon sets; it will bear a red heat, and may be made air-tight by being brushed over with a melted mixture of equal parts of wax and oil.

**Plaster of Paris**. Put some water into a capsule, and keep sprinkling the powder into it. This cement may be made air-tight in the same manner as the former, and is still stronger if mixed up with weak glue. It will bear a low red heat.

**Fusible Fluxes**, for coating tubes, retorts, &c. so as to glaze them, may be made by mixing any clay with one-tenth of its weight of borax; a cream is to be formed with water, which is to be applied with a brush.

**Stourbridge Clay**, ground to a fine powder, makes with water a lute, capable of bearing a higher temperature than any other English lute.

A sufficient number of lutes have now been described for the Laboratory of the experimentalist: it remains then, under this head, only to mention some of the best cements.

**Hard Cement**. That which is most extensively employed, is easily prepared by melting together, in an iron ladle, five parts of resin, one of bees' wax, and adding one part of very fine brick-dust or bole earth, or red ochre, or Venetian red. The compound is to be well stirred together; it may be poured out of the ladle upon a greased stone slab, and, while warm, molded into sticks and kept for use. This cement is well adapted for joining glass vessels, or for stopping cracks. It resists moisture, but, of course, is unable to bear heat or the action of spirits and oils.

A still cheaper kind, for inferior purposes, is made of six pounds of resin, one of red ochre, half a pound of plaster of Paris, and a quarter of a pint of linseed oil. A heated iron rod is the most convenient mode of applying these cements, the first especially.

**Soft Cement**. Yellow wax two parts, turpentine one part, with a little Venetian red to give colour. This cement may be made plastic at any time, by working it a little in the hands, and is extremely convenient for rendering any apparatus air-tight, where heat is not likely to interfere; also for rendering the stoppers of bottles perfectly air-tight.

Glass, or precious stones, may be very firmly united by merely heating them sufficiently to melt mastic, which is to be applied to the whole of the surface of fracture, and the two pieces pressed together so as to leave as little as possible of cement between.

4 M



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**Caoutchouc**, or Gum Elastic, is a useful substance when formed into tubes, or it serves to join glass tubes together for the transfer of gases; for this purpose there is a convenient sort manufactured in sheets by Mr. Hancock, Goswell Mews, Goswell-street-road.

The labels are usually affixed to bottles by gum water, but for this purpose isinglass, dissolved in warm vinegar, is preferable.

**Pasted Paper.** This is a most convenient mode of affixing labels, and also for stopping cracks in apparatus. Mr. Faraday has given a good receipt for preparing it. Take equal parts of powdered gum and flour, and add a little alum, make this into a thin cream with water in an evaporating dish. Keep stirring this mixture over a lamp till it boils, and after it has boiled a few minutes it may be removed, and applied to the paper with a brush. The paper is then suffered to dry, and moistened for use as occasion may require.

Those cements, which are employed for uniting metals, are termed *solders*, and, concerning them, a more particular account will be found in another part of this Work: but as the Chemist must frequently become his own workman, he will have, at times, to experience the great difficulty of making a solder unite with the surfaces of the metals he wishes to join. In Galvanic experiments, few surfaces, which appear to touch, are, in reality, in such contact as to allow of the conveyance of the fluid: hence it is frequently necessary to unite the wires by soldering. Copper and brass wires are prepared for receiving and uniting with common solder, by dipping them into a solution of nitrate of mercury: by this method they are rendered perfectly free from grease, and an amalgam is formed at the surface which materially favours the operation.

**Iron Cement**, such as is used for joining iron pipes, is not often required in the Laboratory. It consists of sulphur one part, sal ammoniac two parts, iron eighty parts. The iron to be clean turnings in small bits, and the whole to be mixed up with a small quantity of water.

**Matrass.** See *Flask*.

**Measures.** The measures of capacity mentioned in the writings of English Chemists, are the wine gallon; its fourth part, the quart; and its eighth, the pint, equal to 28,875 cubic inches. Few modern writers, however, make use of any measure of capacity for gases, except the cubic inch, which forms, undoubtedly, the most Scientific unit.

The following relations are, however, important, as they form part of the Parliamentary regulations enacted in 1825.

The pound Troy contains 5760 Troy grains.

The pound Avoirdupois contains 7000 Troy grains.

The Imperial gallon contains 277,274 cubic inches, or 70000 grains of water. Hence the pint contains 34,66 cubic inches very nearly, or 8750 Troy grains of water.

The cubic inch of water = 252,458 Troy grains.

The cubic inch of mercury = 3125,35 Troy grains.

The standard temperature and pressure for the above being Thermometer F. 62, Barometer 30 inches.

It may be convenient to remember that to convert old measures to the Imperial standard,

Multiply by 0.96943 in corn measure.

Multiply by 0.83311 in wine measure.

Multiply by 1.01704 in ale measure.

And to convert the Imperial into the old measures,

Multiply by 1.03153 in corn measure.

Multiply by 1.20032 in wine measure.

Multiply by 0.98324 in ale measure.

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tion.

The accurate graduation of measures for gases and liquids, is of great importance to the practical Chemist: and for this purpose a very convenient instrument has been already described. See *Graduating Tube*.

When a jar only partly filled with any air is standing over the pneumatic trough, it is evident that the air within is not under the full pressure of the atmosphere, and therefore has its volume enlarged. To know the actual volume under a mean pressure and temperature, a calculation is necessary; (see *Barometer* in CHEMISTRY;) but supposing a jar to be immersed always to the same depth in the trough, say, for example, one inch; then, if it be first filled with water, and successive equal measures of air be admitted from a smaller vessel, the jar may be tolerably accurately graduated as far as pressure is concerned; and in this case, it is evident that the divisions will decrease in distance from each other, proceeding from the top of the jar. Had the jar been graduated by equal volumes, as a tube, it must have been sunk to such a depth in the water, that the fluid within and without might be on a level before any correct estimate of its contained air could have been obtained.

**Mortars.** Of this utensil there should be in the Laboratory several kinds. A large bell-metal one, of Wedgewood's ware, several sizes, fig. 49. A small iron one with a turned cavity. These are so well known, as to require no further description. Fig. 50 represents what is called a diamond mortar. It is used to abrade substances, without allowing any particle to fly off in the operation. This mortar is made of hardened steel. The pestle is *a*, a solid cylinder turned so as to fit the tube *b* accurately, which tube is exactly fitted to the cavity *c* of the mortar.

Fig. 51 represents a section of the agate mortar and pestle, employed for reducing hard mineral substances to an impalpable powder, for analyses after they have been broken down in the diamond mortar.

**Muffle.** Fig. 52, a sort of small oven made of crucible clay, for the protection of cuppels when placed in a furnace.

**Phials** form, of course, a part of the furniture of the Laboratory. There is a kind with a glass cap fitting closely over the common stopper: very convenient for æther, acids, and other liquids producing volatile or noxious vapours.

**Pneumatic Trough.** A vessel calculated to contain water or mercury for the confinement of gases in Pneumatic Chemistry. The water trough may be thus constructed, (fig. 53.) A B is a rectangular vessel of tin or of tinned copper plate, in a wooden frame, and standing on four legs. At the part C the depth of the trough is not more than 2½ inches, and on this part the jars stand when in use. The part D, however, is 10 or 12 inches deep, with a shelf E whereon to rest the jars during the operation of filling; and to facilitate this purpose, there are small holes having inverted funnels beneath; under which the beak of one or more retorts may be placed.

The mercurial trough may be formed by hollowing out a piece of close-grained wood: but the most complete are made of cast iron, and sold at the shops of the Philosophical instrument makers.

**Proof,** a sort of small flask, into which a curved

Chemistry. tube is fitted by grinding. They are plain, fig. 54, or tubulated, fig. 55. For obtaining small quantities of gases, they form a convenient apparatus.

*Receiver.* See *Distillatory Apparatus*.

*Retort.* See *Distillatory Apparatus*.

*Sand-bath.* A vessel containing heated sand, into which retorts and flasks are immersed for evaporation or distillation. They thus receive an equable temperature, and are protected from the immediate action of the fire. The sand-bath may be fitted to the top of a portable furnace; or, if large, may be heated by a flue, and thus form a part of the range of furnaces in the Laboratory.

*Scissors and Shears*, of various sizes, for cutting wire, plates of metal, &c. &c.

*Sieves* of muslin and hair, of different degrees of fineness.

*Soils.* Davy's instrument for the examination of, fig. 56.

*Syphons*: for drawing off the clear liquor from above precipitates.

*Tubes* of glass, porcelain, platinum, iron, caoutchouc, &c. &c.

*Tubes graduated*: are generally about half an inch in diameter, and about a foot long: they are used in delicate experiments on gases, and are commonly divided into parts of a cubic inch, by a method already explained under *Measures*.

*Tube, dropping or sucking.* This very useful little instrument has been already noticed, fig. 18. At the lower end is a very small orifice, which being introduced into the clear fluid from which a precipitate has subsided, by suction with the mouth at the upper orifice, the bulb of the tube may be filled with fluid, and on closing the orifice with the tongue, the tube may be removed without the loss of one drop of the fluid. Thus, by repeating the process if necessary, a precipitate may be obtained nearly free from all supernatant fluid, without occasioning any disturbance in it, and the objectionable use of a filtre is avoided.

*Tubes of Safety.* To guard against the effects of absorption on the one hand, or expansion on the other, the tubes of safety are employed. Figs. 57 and 58 represent the two kinds. Suppose the tube, fig. 57, to be fitted by passing through a cork or cement into the tubulature of a retort or Woulfe's bottle; and that so great a pressure from the expansion of gaseous matter took place, as to endanger the bursting of the vessel. In this case the bulb C is about one-third filled with mercury, and as the pressure takes place upwards, some portion of the gas will escape; but the mercury retaining its place, will suffer no return of atmospheric air to the vessel.

Next, suppose that in a retort to which the tube, fig. 58, is affixed, a condensation of the gaseous contents takes place, so that absorption may be commencing at the beak of the retort, the cold fluid entering would infallibly break the vessel. But the bulb containing mercury, as in the former case, though differently arranged, will suffer some of the atmospheric air to ascend through the tube, and thus restore the equilibrium.

Fig. 59 represents a Woulfe's bottle, having a tube of safety, formed of a small glass tube, passing through a cork, and dipping half an inch below the surface of the fluid in the bottle.

*Tube transferring*: is not in very general use, but is, nevertheless, a convenient instrument, and is thus described by Dr. Thomson:

"It is often necessary to transfer determinate quantities of gas from the water trough to the mercurial trough. This must be done without introducing any water along with the gas, except what may exist in the gas in this state of vapour. This is done with the greatest facility, by means of the tube represented in fig. 60, which was first used, we believe, for the purpose in question, by Mr. Cavendish. This is a glass tube open at both ends: but one of the extremities is bent round, and is drawn out into a fine capillary bore. The tube is graduated into 100th parts of a cubic inch, and the degrees should be made as conspicuous as possible. A good method is to fill the lines after they have been cut in the glass with black or red sealing-wax. When we want to transfer a given bulk of gas from the water trough to the mercurial trough, we fill this tube with mercury, and shutting the end *b* with the finger, we introduce the end *a* into a glass jar standing over water, and filled with the gas to be transferred. On removing the finger from the extremity *b*, the mercury falls down, by its weight, into a vessel placed at the bottom of the trough to receive it, and the gas enters by the capillary extremity *a* to supply its place. When the gas admitted into the tube amounts to the quantity desired, (half a cubic inch for example,) we shut the end *b* with the finger again. We then withdraw the tube from the water trough and wipe it dry. The end *b* is now to be placed uppermost, and the end *a* introduced under the bottom of the glass jar (filled with mercury, and standing over the mercurial trough) destined to receive the gas. On removing the finger, the weight of the mercury in the tube forces out the gas. When it has all made its way into the destined test glass, we remove the tube; and we may, in the same way, introduce an additional quantity of any other gas, till we have made up the intended mixture."

*Tunnels*, of pewter, glass, and Wedgewood's ware. Glass tunnels employed for filtering, should have raised ribs of glass running from the top towards the lower orifice for the escape of the liquid. Without this contrivance, the moist paper adheres to the sides of the glass, and the process is very materially retarded. Sometimes glass rods, or bits of straw are placed between the paper and the glass to answer the same purpose.

*Weights.* See *Measures*.

*Woulfe's Apparatus* is represented in fig. 61. By an inspection of the figure, it will be evident that if A be a tube through which gas is passing from a retort, for the purpose of being absorbed by the same or different liquids in the two tubulated bottles: the vertical tube in the centre will prevent any liquid being forced from the second bottle into the first, in case of absorption; the gas which does not combine with the liquid in the first vessel, will pass into the second, and if not there absorbed, may pass into a third similarly disposed, or to a pneumatic trough by the tube B.

For further information, consult Faraday on *Chemical Manipulations*, and an *Explanatory Dictionary of Apparatus and Instruments employed in the various Operations of Chemistry*, Lond. 1824. Also Aikin's *Chemical Dictionary*, 2 vols. 4to.

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## Introduction.

Arrangement.

(1.) It may be reasonably expected, that something should here be premised with regard to the Arrangement that will be adopted in the following SYNOPSIS OF CHEMICAL SCIENCE. The difficulties that immediately present themselves on commencing such a task, are well known to every Chemist. We might, perhaps, safely shelter ourselves under the authority of some well-known writer, and adopt the system which he has made use of. This, however, is not our intention; but we shall lay before our readers an arrangement which to us seems better adapted to the nature of this Work than any that we could thus select; not that we are confident of its being intrinsically better for all purposes, or that it ought to be generally adopted; for we are fully convinced, that as the Science itself is only in a progressive state, and by no means advanced to maturity, future discoveries must greatly change, and may indeed altogether overturn those fundamental positions upon which all our existing Systems rest. We possess among the English, German, and French writers, several excellent general Treatises on this subject; but the fact of no two of these writers having adopted a similar arrangement, must show that great diversity of opinions exist upon the subject; and that the voice of universal consent has not called any one Scheme to the post of preeminence; and therefore cannot condemn a writer for arranging the Facts of this Science in whatsoever order may seem to him best fitted for explaining its Laws and Principles.

There is, however, a sort of presumption in favour of a Synthetic method of describing, first, all the Simple bodies, and then the Binary compounds, and next the Ternary, and so on; to be derived from the fact, that Thomson, Thenard, and Berzelius, the three best Systematists, have all, more or less, adopted it. Our reason for departing from a plan sanctioned by such high authorities is this; that as the properties of a Simple substance, which it is the Chemist's province to investigate, are, in fact, mainly developed in its power to enter into the combination of more complex bodies, the Principle of such an arrangement is perpetually and necessarily violated. Thus, for instance, one of our most able writers professes to describe the Element Iodine; and, according to his System, Iodic Acid, a Binary compound, ought to appear in a different part of his Work; whereas he finds himself compelled to describe the Acid in treating of the properties of the Simple base. This is no solitary case; the properties of the more Complex substances are so constantly starting up before us as characteristics of their Elements, that the same evil pervades every portion of such a Classification. We admit that it has a less appearance of Philosophical arrangement to describe any one Elementary substance, and then to pursue it through all its more complex forms, for the production of Proximate Elements; but we think that by such a method the properties are more readily studied in connection with each other, leaving less probability of repetition or omission. All must have experienced the difficulty of hunting through the properties of one substance, described in several parts of the same Work.

Whatever be the truth in these particulars as referring to a complete Code of Chemical Science, we feel per-

suaded that the Plan which we have here adopted is better suited to a Synopsis like the present, which must be limited to a moderate magnitude, and having its peculiar characteristics as a Work of reference only. We profess to give a Summary of the properties of each known body; and it is of obvious importance that these should be arranged in such a manner as to be most ready of access; but to extend the utility of our pages we give also a series of references to direct the Student, who may wish to pursue any research more in detail, to all that is valuable on the subject.

(2.) As it happens with regard to some substances, that either subsequent discoveries or differences of opinion on points of theory have introduced more than one name for the same substance, we have in such cases affixed the Synonymes to the head of each subsection. The Chemical Symbols for the Simple, and also for many of the Compound bodies, will be found from the Tables in the Appendix, but may, in some cases, be conveniently introduced before.

Generally speaking, we refer the more complete description of any compound to its second appearance in this Treatise: thus if A and B unite to form a Proximate Element, we mention the combination under the Section describing A; but reserve the description of the substance to the Section on B, for the sake of becoming acquainted also with the ordinary properties of the Element B; but this rule is not quite invariable. At times we find ourselves compelled to speak of the action of a substance, to which the Scheme may hitherto not have conducted us. In extenuation of this apparent dereliction from the just laws of System, we would urge that no reader is in reality so little acquainted with the Chemical Elements as not to know them by name when the word may occur to him.

We have found it convenient also not to insert the Atomic Weights of bodies in the text, except for some specific purpose; but all these, as well as the Specific Gravities, will be given in a tabular form in the Appendix.

(3.) In pointing out to the Student those Works from the perusal of which he will derive the greatest advantage, we may be frequently understood as making our acknowledgments to those Writers to whom we feel under the greatest obligation for the assistance they have afforded us in arranging this Treatise.

As the most Elementary Work, we recommend the *Conversations on Chemistry*, in two volumes 8vo.; a much larger and more Scientific Work also in two volumes, by Dr. Henry. There has also been recently published a very good Work in one volume 8vo., by Dr. Turner; and Nicholson's *Chemical Dictionary*, with additions by Dr. Ure, will be found to contain much useful matter.

The four great Systems of Thomson, Murray, Thenard, and Berzelius, are all Works of first-rate merit. The first abounds in valuable facts and extensive reference; the second is a Work containing much of the Philosophy of Chemistry, written in a very continuous and pleasing style; M. Thenard has given extensive generalizations, which are of the greatest importance; and the last edition of the System of Berzelius, seems not unworthy of the reputation of that most distinguished and indefatigable Philosopher. The original is in Swedish; and we conclude that it is not yet completed, as we are in possession of only the first five half volumes of a German translation, which is published at

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Books.

### Scheme.

## PART I.

## PART II.

**CHAP. III. Non-metallic (Electro-positive?) Elements.**

§ 1. Silicon.

§ 2. Hydrogen. Subsect. 1. Water (Protox. of Hyd.)  
Subsect. 2. Deutoxide of Hydrogen.

§ 3. Carbon ... Subsect. 1. Carbonic Oxide.  
• • Subsect. 2. Carbonic Acid.  
Subsect. 3. Carburetted Hydrogen.  
Subsect. 4. Olefiant Gas.  
• Subsect. 5. Bicarburetted Hydrogen.  
Subsect. 6. Quadro-carburetted Hyd.  
• Subsect. 7. Naphtha of Coal Gas.  
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• § 4. Boron..... Subsect. 1. Boracic Acid.

• § 5. Phosphorus. Subsect. 1. Phosphoric Acid.  
Subsect. 2. Phosphorous Acid.

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## PART III.

## PART IV.

PART V.

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## PART I.

### CHAPTER I.—IMPONDERABLE AGENTS.

#### INTRODUCTION

Chemistry. (5.) It has been usual in Systems of Chemistry to enter rather fully into the History and Effects of the four substances or properties, (be they which they may,) the names of which are comprised in our first Part. This was more especially the case with the first and third; and was a necessary consequence of the method in which these Sciences had been studied. This necessity, however, no longer exists; each of the four, *viz.* Caloric, (Heat,) Light, Electricity, and Magnetism, having vindicated to itself a separate rank among the Sciences: and each has very properly formed the subject of a separate Treatise in this *Encyclopædia*. We name them here, not for the purpose of repetition; not with the design of entering at large upon the general doctrines of each of these Sciences; but only to mark their connection with *Chemistry*, and to describe the *Chemical Effects produced upon the Elementary Molecules of Matter by their Influence*: viewing them strictly in the light of *Agents*; means employed to effect Chemical purposes. Future researches may, it is true, show that some one or other of these forms the Spring and Principle of Chemical Affinity; or, on the other hand, it may appear that Chemical Affinity is the influential agent for the developement of some of these Physical Properties: but, in the uncertainty that at present exists, we consider the arrangement we have adopted as best calculated to elucidate the principles of our Science.

#### § 1. Chemical Agency of Caloric.

Caloric. (6.) Caloric is the term made use of to designate the cause of Heat; the comparative absence of Caloric, or its presence in a less degree, we call Cold: these are but terms of ordinary language, and not very precise in their meaning. The real nature of Caloric is at present unknown. By some it is supposed to be actually a fluid substance; by others, only a property of matter. Should the former supposition be correct, we need only observe, that its tenuity is such as to have hitherto eluded all efforts that have been made to prove that it possesses any gravitating power. Under either view, therefore, we are justified in calling it one of the Impponderable Agents. The numerous and highly important Physical Properties that it exerts upon all material Bodies have already been examined in our Treatise upon HEAT. In Art. (108.) of that Treatise we have marked out what we conceive to be the just boundary between the effects of Caloric upon Physical and Chemical Science; or, in other words, we have separated its effects into those which take place upon the Integrand Molecules of Matter, from those which take place upon the Constituent ones. The latter alone fall within the scope of this Treatise

Part I. It is obviously essential to the sort of action that we now suppose, that there should be present dissimilar elementary Molecules in the Chemical sense of the word; these we are to consider either as combined or uncombined. If the Molecules be combined, Caloric may produce Decomposition; if uncombined, and the Molecules be conveniently disposed for the operation to take place, Caloric may effect their union.

(7.) The cases of Chemical Decomposition effected by Heat alone, are, perhaps, neither very numerous nor very distinctly marked. The general operation of increased Heat upon all matter tends to convert it successively from the Solid to the Liquid, and from the Liquid to the Gaseous form. But should no extraneous matter be present, decomposition does not frequently take place. It is true, that where Molecules chemically dissimilar are in union, and these are very unequally affected physically by the action of Caloric, decomposition may readily ensue. To select a familiar instance, let any alloy of Mercury, with some metal of difficult volatility, be heated beyond the boiling point of Mercury; the Mercury will rise in vapour, and break from its Chemical combination with the less volatile metal. This is, however, in great measure a Physical operation; for in the commencement of our experiment the dissimilar Molecules of the two metals are united by their Chemical Affinity, with a force surpassing that by which the Molecules of the more volatile metal tend to separate, and to assume the Gaseous form. But, by further accession of Caloric, this latter force increases to such an extent as to overpower the former one, and decomposition ensues.

(8.) Nevertheless there are instances in which, as far as we can judge, the Physical effects upon the dissimilar Molecules of a compound body are equal; and yet, by increase of Temperature, decomposition is produced. For instance, the gas called Protoxide of Chlorine (Euchlorine) undergoes decomposition, and its Gaseous Elements separate, upon exposure to a very moderate increase of Temperature.

(9.) On the other hand Caloric, or its effect Heat, seems to be a powerful promoter of Chemical combination. It is well known that many Elementary bodies, when placed in contact, and heated, enter into Chemical union. But here also it is difficult to say precisely how much of this effect is truly Chemical and how much Physical; how much is due to the change of Molecular affinity produced by the Heat, and how much to the state favourable to union, arising from a change in the Physical constitution of the bodies acted upon.

(10.) Hitherto we have limited our remarks to the action of Caloric either upon two or more dissimilar bodies not in union, or upon one compound body. But the case which is of more frequent occurrence to

Effects. Decomposition

and Combination.

**Chemistry.** the Chemist is, when either a compound body and an Elementary body, or two, or even more, Compound bodies are acted upon simultaneously. In these cases the practical effects of Caloric are very considerable. Whatever be the original state of the Chemical Affinities between the Molecules concerned, Heat will very often modify these Affinities, and facilitate the production of new combinations. In this view Caloric is one of the most important agents in the hands of the Chemist. It frequently aids us in forming combinations, which otherwise we are unable to effect; it promotes solution, in part possibly, by being itself a great antagonist to Solidity; and it seems almost always to be the spontaneous concomitant of all violent degrees of Chemical action.

## § 2. Chemical Agency of Light.

**Light.**

(11.) The only part of the history of Light which we conceive to belong to the subject now before us, is its agency in promoting Chemical composition or decomposition. For its general properties see the Treatise on Light.

Scheele noticed some of the decompositions produced by Light, and examined the conditions necessary to the success of the experiment. Oxygen, when held by a light affinity, may be separated by this agent; and this extends to metallic oxides of that kind even when combined with an acid. Thus Scheele, having evaporated a solution of gold to dryness, again dissolved the salt in distilled water, and placed the solution in a glass-stopper bottle. The bottle was then exposed to the sun's rays, and in a fortnight the surface became covered with a pellicle of reduced gold. (a.) Mrs. Fulhame also, in her *Essay on Combustion*, states, that a piece of silk, which had been dipped in a solution of gold, was exposed to the sun's rays and kept rather moist; it was at first yellow, then became green, then purple, then showed spangles of gold; and at the expiration of an hour the whole piece of silk was covered with a film of metallic gold. Another piece of silk was similarly treated, and put into a dark place, in which it remained three months without undergoing any change save the acquisition of a brownish tint. Silver also in solution was reduced by the action of Light, while in the dark it underwent no alteration. Many very amusing experiments of this nature may be seen in Mrs. Fulhame's *Essay*. (b.)

**Decomposing Power.**

(12.) In nitric acid the oxygen is retained by a feeble degree of affinity. If a bottle containing this acid be exposed to the sun's Light, it first becomes yellow, then orange, by the separation of a part of its oxygen. But if the same bottle be quite full and closed with a glass stopper, no such decomposition can take place from the mechanical obstacle opposed to the escape of the oxygen. (c.) Berthollet found that a bottle so exposed to the sun's rays, and provided with a bent tube to convey the gas to a Pneumatic trough, produced a considerable quantity of oxygen in a very few days. (d.)

(13.) If a piece of paper moistened with a solution of nitrate of silver, or if a portion of the precipitated muriate of silver (which is a white powder) be exposed to the sun's rays, a very few minutes are sufficient to change the colour almost black. It is believed, that in these changes the acid is frequently removed, wholly or in part, as well as the oxygen from the metal. Berthollet contrived that this colorific process should take place under water; and he found that a portion of the

acid had in fact separated from the oxide and remained in the water. (e.)

(14.) Scheele proved that it was to a true Chemical agency on the part of Light, and not to its Heating power, that these effects were to be attributed. For this purpose he exposed the same substances which he had found to change so readily, but in phials covered with black paint. The phials became very hot, but even in several days' exposure no Chemical effect was produced upon the substances within. (f.) This fact was further confirmed by Berthollet. Rumford, however, adduced experiments in opposition to this doctrine, and endeavoured to show, that the effects produced were due to the Heat alone. He obtained a partial degree of reduction, by exposing pieces of silk, which had been dipped in metallic solutions, to the Light of a candle. He produced the same effect by placing small pieces of charcoal in a tube with some solution of gold or silver, and then exposing the whole to the Heat of boiling water, the metals were reduced on the surface of the charcoal. (g.) The first experiment we conceive proves only that the Light of the taper tended, in some degree, to produce the same effect which the sun's Light would have accomplished more speedily and completely. The second case also was proved to be fallacious by Berthollet, who showed, from the gas evolved, that the decomposition had been caused by the direct action of the charcoal. (h.)

(15.) Having thus adduced instances of Decomposition, produced by the action of solar Light, we must now show that it possesses, in a very marked degree, the opposite property in certain cases of determining combination.

Mr. Dalton remarked when Chlorine and Hydrogen gases were mixed together, Light had a material effect upon the rate of the Chemical combination which resulted. Thus in a feeble Light the union took place but slowly, but if the mixed gases were exposed to the direct rays of the sun, the combination was so rapid as to be frequently attended with an explosion. (i.) MM. Gay Lussac and Thenard observed the same fact, and found that it even held good with the compound hydrogenous gases when mixed with Chlorine. (k.)

Berthollet had previously shown that if a solution of Chlorine in water were exposed to the sun's Light in a flask, provided with a bent tube to collect the gaseous product, oxygen was evolved. (l.) The Chlorine decomposed the water, uniting with the hydrogen to form muriatic acid, and hence the escape of gaseous oxygen. Chlorine and carbonic oxide are not readily brought to combine, even under considerable elevation of temperature, but by exposing the mixture to solar Light the union is effected.

(16.) To solar Light then we must allow a considerable power of Chemical action, but we shall find that the different parts of the solar beam differ greatly in this power. Scheele first remarked that when the solar spectrum was cast upon a piece of paper, impregnated with muriate of silver, it became black much sooner in the violet than in the other coloured rays. (m.) Senebier repeated this experiment, and estimated the comparative powers thus. The same tint produced upon the muriate of silver by 15 seconds' exposure to the violet ray, required for its production 23 seconds in the purple ray; 29" in the blue; 37" in the green; 5½ minutes in the yellow; 12 minutes in the orange; and full 20 minutes in the red rays. (n.) Sir H. Engle-

Part I.

Promotes combination.

Chemistry.

field found that the blue ray had a greater power than the other rays in communicating the luminous property to Canton's Phosphorus. Seebeck found that when a mixture of Chlorine and Hydrogen gases was exposed to the solar Light, under a red glass, the combination took place but slowly, but that under a blue glass the union was instantaneous; with several other similar facts. (o.)

(17.) The existence of calorific rays beyond the extreme limit of the visible red ray of the spectrum, suggested the possibility of a similar set of Chemical rays beyond the opposite, the violet end. This inquiry seems to have been pursued by Dr. Wollaston and M. Ritter simultaneously. They both found that there was a set of Chemical rays of greater refrangibility than those of Light and of Heat. Ritter came fully to the conclusion that, besides the visible rays of the spectrum, there were two other sets of invisible rays: one of which being less refrangible than any of the luminous rays, was found beyond the red end of the spectrum, having a greater calorific power than the colorific rays, and tending also to promote oxidation: the other set of invisible rays being more refrangible than the colorific rays, was found beyond the violet end of the spectrum, being inferior to the colorific rays in heating power, and tending to the separation of oxygen from its combinations. (p.) Dr. Wollaston made use of muriate of silver also, and arrived at a similar conclusion. He employed also guaiacum, which changes from a yellow to a green colour by exposure to Light; and this, from the absorption of oxygen, as is proved by the process succeeding better when the gum is placed in oxygen gas. There was, however, this peculiarity, that the change was promoted at the violet end of the spectrum, while in the red extremity the yellow colour might be restored. This fact, then, is hostile to the universality of Ritter's law. (q.) Berard amply confirmed these experiments; he divided the spectrum into two portions, and then concentrated the rays of each portion with a lens. The part from the red to the green produced a brilliant Light, but the muriate of silver remained in it for more than two hours quite unaltered. The part from the green to the violet inclusive did not by its concentration produce a very vivid Light, but blackened the silver in less than ten minutes. Hence we learn that the deoxidating power of the rays decreases very rapidly in passing from the violet to the red end of the spectrum. (r.)

(18.) It would appear, also, that there is an analogous difference in the Chemical action of artificial Light produced from different sources; for Mr. Brande has stated that the Light produced by the combustion of oil gas, coal gas, or olefiant gas, even when concentrated so as to produce a considerable degree of Heat, effects no change on the muriate of silver, nor yet on a mixture of Chlorine and Hydrogen; but that the Light from charcoal, ignited by the voltaic battery, speedily colours the muriate and unites the gases. He could obtain no Chemical action from the Light of the moon. (s.)

Some other experiments of Ritter in the paper formerly mentioned are very curious, and the report of MM. Berthollet and Biot, upon Berard's experiments, is well worthy of examination. (t.)

(19.) Some experiments of M. Chaptal tend to prove that the process of crystallization is influenced by the presence of Light. He found that when a number of capillary crystals were shooting up the sides of a vessel

containing a saline solution, the effect took place only on that side of the vessel that was illuminated. He was thus able to cause the crystals to form on any one side, and by placing a screen against the vessel the line between Light and darkness was distinctly marked by the limit of the crystallization. This phenomenon was most easily observed in metallic salts. (u.)

(20.) "The operation of Bleaching affords another example of the Chemical changes which Light is capable of producing. Colour is in that case removed, and this depends equally on the transfer of oxygen, the colouring matter of the thread receiving that principle probably from the decomposition of the water with which the substance to be bleached must be supplied. This formed the old method of bleaching; and the substitution of the Chlorine in the new mode, establishes this theory of the changes of which the operation consists.

"Even the processes of animated nature are influenced by the Chemical agency of Light. Organization, sensation, spontaneous motion, and all the operations of life (says Lavoisier) exist only at the surface of the earth, and in places exposed to the influence of Light; and without it nature itself would be inanimate. Its operation in vegetation is strikingly exemplified in the adaptation of plants to particular climates. Those which grow under a clear sky, and an intense solar light, are in general more pungent, odorous, and aromatic, than those which are placed under the opposite circumstances; and plants which are the natives of a warm climate will not grow or produce their fruit in situations where they are less exposed to its genial influence. The artificial exclusion of Light from vegetables, giving rise to the process named Etiolation or Blanching, affords another proof of its action on vegetation. The plant always extends its branches towards any opening at which light may enter: and if this be closed, and another opened in a different situation, it changes the direction in which it was shooting, and still turns towards the Light; and in this way, as M. L'Abbé Tessier has shown, plants may be made to grow in any direction. If kept in perfect darkness, they become feeble, succulent, insipid, and of a white or yellowish colour, while, if transferred to a situation where they enjoy the solar rays, they regain their green colour, and become vigorous. These changes from the exclusion of Light appear to be owing to the accumulation of oxygen in the plant, as, under its influence, this principle is disengaged from their leaves, derived probably from the decomposition of water, and perhaps of other compounds subservient to vegetable nutrition. According to the experiments of Tessier and Decandolle, the Light emitted by a lamp gives even a green colour to the leaves, though less deep than that from the light of day. The Light of the moon has a similar effect. (v.)

(21.) "Nor are animals exempt from the influence of this important agent. Deprived of it they suffer nearly the same changes as vegetables do, and the darkness of their colour is in general greater according to the intensity of the Light to which they are habitually exposed. Insects which live underground are usually of a light shade; the animals of the Arctic regions are almost all pale or white, while those belonging to the tropical countries are distinguished by the variety and brilliancy of their hues. Even in Man we trace a gradation of colour proportioned nearly to the climate in which he resides." (w.)

Part I.

Affects  
crystalliza-  
tion.

Chemistry.

References from (10.) to (21.) inclusive.

References.

(a.) Scheele's *Essays on Air and Fire*, p. 83. (b.) Fulhame, *Essay on Combustion, &c.* p. 151. (c.) Kirwan, *Note to his Translation of Scheele's Essay, &c.* p. 230. (d.) *Jour. de Phys.* xxix. p. 82. (e.) *Chemical Statics*, vol. i. p. 147. (f.) *Essay on Air and Fire*, p. 96. (g.) Rumford's *Philosophical Papers*, p. 341. (h.) Berthollet, *Chem. Stat.* i. p. 149. (i.) Dalton, *Syst. Chem. Phil.* p. 300. (k.) *Mém. d'Arcueil*, vol. ii. p. 347. (l.) *Jour. de Phys.* xxxix. p. 81. (m.) *Essay on Air and Fire*, p. 91. (n.) Senebier, *Mémoires Physico-Chimiques*, tom. iii. p. 199. (o.) Seebeck, *Nich. Jour.* xxiv. p. 220. (p.) Ritter, *Nich. Jour.* v. p. 255. viii. 214. (q.) Wollaston, *Nich. Jour.* viii. p. 293. (r.) Berard, *Nich. Jour.* xxxv. p. 256. (s.) Brande, *Phil. Trans.* 1820, p. 11. (t.) Berthollet and Biot, *Nich. Jour.* xxxv. p. 257. (u.) Chaptal, *Jour. de Phys.* xxxiii. p. 297. (v.) *Mém. de l'Acad. des Sciences*, 1783, p. 155. (w.) Murray's *Chemistry*, vol. i. p. 561.

### § 3. Chemical Agency of Electricity.

Electricity.

(22.) According to the Principles already proposed, this Section will be devoted to an account of the *Chemical effects of Electricity*; including those which are produced by the application of the Voltaic Pile, as well as those which proceed from the common Electrical Machine. That these two instruments only produce different modifications of the same great Physical Agent we have already explained; and therefore for the future, when we speak of the Electrical agency by which any Chemical change is to be effected, we would be understood to refer to an operation producible either by ordinary, or by Galvanic Electricity, though much difference may exist as to the actual fitness of these respective modifications of Physical force, with reference to the purpose intended.

Electricity existed for many years as a Science, previous to the discovery of its intimate relations to Chemical Affinity, and this discovery did not take place until Voltaic Electricity had become known to the Philosophers of the present Century. Galvani's discovery of what he termed Animal Electricity, which was in fact the Electricity of the contact of dissimilar Elements, took place accidentally in 1791. It was succeeded by about ten years of active research made by the Philosophers of all Europe; but as the great problem which they investigated with so much zeal, was the necessary conditions of the probable theory of muscular contraction produced by this species of Electricity, no immediate profit accrued to Chemical Science. At length, in 1800, Volta, by a fair system of reasoning upon the effects of Metallic contacts, was led to construct the Pile. His end was fully answered when he had obtained a series of most interesting Electrical effects highly important to the Theory which he was labouring to establish. The history of this discovery was communicated to Sir Joseph Banks, who laid the letter before Messrs. Nicholson and Carlisle. (a.) By these gentlemen the experiments of Volta were repeated and verified: they discovered the positive and negative Electricities of the opposite ends of the Pile; and accidentally stumbled upon the great discovery of the first Chemical decomposition effected by Electricity. They had formed a part of their cir-

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cuit by water, and observing small bubbles of gas to be disengaged, apparently from the wires in the water, they found that this gas had the smell of Hydrogen. The important remark was not lost upon these experimentalists, who, pursuing the research, fully demonstrated the decomposing power of the Pile. They found that at one wire Hydrogen Gas was evolved, while the other wire became oxidated; and by employing wires of Platinum they obtained Oxygen and Hydrogen Gases from the two wires respectively, and in such proportions as to form water. Such was the origin of this most important series of discoveries. (b.)

Mr. Cruickshanks, an eminent Surgeon at Woolwich, immediately verified these discoveries, and added to them that of the reduction of metals from their solutions, and the decomposition of the Neutral Salts. Cruickshanks also invented the Trough. Dr. Henry of Manchester decomposed the Nitric and Sulphuric Acids; and also resolved Ammonia into its Elementary Constituents. At length Sir H. Davy commenced that splendid series of researches which have tended more than those of any other individual to explain the Electrochemical relations of the molecules of bodies; and have not been surpassed in acuteness of investigation, or brilliancy of result, by those of any individual that ever lived, if we except the sublime discoveries of the great author of the *Principia*. It were unjust not also to mention the valuable contemporary researches made in Paris by Humboldt, Gay Lussac, and Thenard; though we do not enter upon any minute historical description of them in this place, but refer our readers to the Treatise on GALVANISM.

(23.) For the best proofs of the identity of ordinary Identity of and Galvanic Electricity we are mainly indebted to Agents. Dr. Wollaston. The question has been long agitated; and perhaps to some, may not even yet appear to have been satisfactorily decided. The sensation, however, produced upon the human frame is substantially the same, whether from the Leyden Jar, or from the excited Voltaic Pile. The rapidity of communication is the same in both cases. The conducting powers of all bodies are identical to both fluids. The spark is in both cases visible when the discharge takes place through a thin stratum of air. The Pile in activity will charge a Leyden Jar either positively or negatively, according to the Pole with which the connection may be established. The Electrometer serves as a measure of Tension for both instruments. And the Chemical changes which may be produced by developing the Polarities of elementary or constituent molecules of bodies, are the same in kind, whichever agent be employed. (c.)

(24.) Before we proceed to the actual Chemical Most useful agencies of the Pile it may be well to mention those Voltaic arrangements which are best adapted to the purposes intended. This we say with reference chiefly to selection, for as the actual construction of Galvanic Apparatus more properly belongs to the general Treatise on that subject, to it we refer our readers.

(25.) The simple Galvanic circle consists of three more or less perfect conducting substances. It may be formed either of two perfect conductors and one imperfect conductor; or of two imperfect conductors with one perfect conductor. These terms were introduced by Sir H. Davy, in whose Work various arrangements of both sorts may be found. (d.) But as the

4 L . .

**Chemistry.** effects produced by any simple Galvanic Circuit are feeble; especially with reference to Chemical action, it is usual to form compound Galvanic Circuits or Batteries. These consist simply of the reiteration of a number of simple alternations. The metals and the liquids are arranged in various forms, as Troughs, Piles, or Spirals. In practice Copper and Zinc are the metals usually employed; producing a combination of great energy at the least expense.

(26.) For igniting or fusing Metallic wires, or in other words, for producing great Heat by generating a very considerable quantity of Electricity in a short time, so as to produce Heat in its passage through a conductor comparatively perfect, plates of large surface are required. But for producing Chemical Decomposition large plates are not necessary: the number of the plates is, however, of essential importance; they may be small, but they must be numerous. The *Couronne de Tasses* of Volta is an excellent arrangement for Chemical purposes: but on the whole the Battery we can most strongly recommend, should consist of plates from four to six inches square, arranged after Dr. Wollaston's plan in Wedgewood Troughs.

**Charges** (27.) Though water and saline solutions are sufficient to excite the Chemical action of a Battery, yet weak acid liquids are most efficacious. For Chemical purposes the acid may be used in a highly dilute state: Mr. Singer, who made many experiments on this subject, recommends one part of Sulphuric Acid with two or three of Nitric Acid, and from forty to sixty parts of water, as an efficacious and enduring charge.

Where long-continued action is required, without great intensity, a solution of common salt, with the addition of a little Muriatic Acid, forms an economical and sufficient charge. Those effects which are purely Electrical are best developed by a charge consisting of a weak saline solution; or even of spring water only.

**Chemical action.** (28.) We now arrive at that which is the legitimate object of this Section; viz. the Chemical action of the Pile. If any compound body, which is itself a conductor, or which can be made even partially so, be placed between two wires connected with the Poles of the Battery, so that the substance itself shall form a part of the Circuit, the Elementary molecules of that body will undergo certain changes in their forces of Polarity, and in many cases to such an extent as to overcome the Affinity which formerly bound them together in Chemical combination.

For example, let two Platinum wires from the opposite Poles of the Battery be placed at any distance from each other in the same vessel of water; bubbles of Gas will be disengaged at the extremities of each wire; the quantity issuing from that part of the water in contact with the wire proceeding from the Negative Pole of the Battery is, in volume, double of that issuing from the other wire which constitutes the Positive Pole: and if these gases be collected, as they easily may by inverting test tubes filled with water over them, the former is found to be Hydrogen, the latter Oxygen Gas. Now these are known to be the just constituents of water, and if the gases be again mixed and exploded by the Electric spark, water is reproduced without any residuary matter.

If the wire forming the Positive Pole be of copper, or any oxidable metal, the oxygen never assumes the gaseous form, but unites with the metal so as to produce a metallic oxide.

If in a similar manner the wires be introduced into a strong solution of Sulphuric or Phosphoric Acid, Oxygen Gas will rise from the Positive Pole and the inflammable Element will collect round the wire connected with the negative Pole.

Part I.

(29.) The following is found to be the general Law **General Law.** of these decompositions, viz. that the non-metallic bodies, (sometimes thence called Electronegative,) Oxygen, Chlorine, Fluorine, Iodine, and Bromine, with all Acids, are found at the Positive Pole of the Voltaic Circuit, while the Electropositive non-metallic Bodies, (combustibles of some writers,) the Metals, Alkalis, Earths and Oxides, in short all bases, tend to the Negative Pole or surface.

(30.) The following singular extensions of these properties were discovered by Sir H. Davy in 1806 and 1807. **Transfers.** If the Polar Wires do not dip into the same mass of water, but into separate vessels of that fluid, having a connecting metallic wire between them, the decomposition still takes place; Hydrogen Gas is evolved from the one wire, and Oxygen from the other. The same takes place if the connection between the two vessels of water be made by moist fibres of Cotton, Ammianthus, or any other conducting substance.

To understand these interesting experiments of Sir H. Davy; suppose two Agate cups marked P and N to denote the Poles of the Battery with which they were connected; Positive and Negative respectively. Sulphate of Potash, or Soda, was placed in N and distilled water in P; the connection between the two cups was established by moist fibres of Ammianthus. The Acid passed over to the cup P, and the solution in the cup N, which was at first neutral, became alkaline. A converse experiment was made by placing the saline solution in P, and distilled water in N. In this case the water became alkaline, and pure Acid remained in the cup P.

In another experiment when Nitrate of Silver had been placed in the cup P, the Ammianthus leading to the cup N was coated with a film of metallic Silver; thus showing that an actual and substantial passage of the Element took place along the connecting substance.

The same results obtain if a third cup M, containing pure water, be placed between P and N, so as to form a part of the connecting circuit, while the water remains pure, though the Acid and the base have both been transmitted through it.

Again, let the three cups be arranged as before; having Sulphate of Potash in N, a weak solution of Ammonia in M, and pure water in P. In this case, to arrive at the cup P the Sulphuric Acid must pass through a free Alkali for which it has a very strong Affinity: yet in five minutes this was effected with a Battery of one hundred and fifty pairs of four-inch plates. Thus the ordinary forces of Affinity were suspended or overpowered by that of Electrical Polarity. In the same way, strong Acids were made to pass through strongly alkaline solutions, and alkalis through strongly acid liquids, without entering into combination.

It was by reasoning upon these facts, that Sir H. Davy contrived to apply the decomposing power of the Pile to the exhibition of the bases of the alkalis and alkaline earths, and thus arrived at a series of results as novel as they were important. (c.)

(31.) Strictly speaking, there can be no Electro-



Chemistry.  
Bodies must  
conduct.

chemical action upon a substance that is a Nonconductor; and yet some adventitious circumstance may induce a sufficient degree of conducting power to bring the Elementary molecules of the substance within the reach of the Electrical action, so that their Polarity may be affected and decomposition produced. For example, Glass is a nonconductor, and yet where Electrochemical experiments are made in glass vessels, a slight decomposition of the surface will sometimes be manifested by the setting free of a portion of its alkali. In this case the water or liquid forms the mean of communication for a sufficient Electrical power to the molecules of glass immediately in contact with it.

Metals  
burned.

(32.) Among the most usual Galvanic experiments are those in which metallic wires or leaves are either fused or burned by the discharge of a Battery. The metals are all comparatively perfect conductors; but the circumstance of their becoming heated at all by the Electrical discharge, seems to us a proof that they are not strictly so. By a perfect conductor we should understand a body which would instantaneously allow the passage of any quantity of Electricity without reference to the superficial magnitude of the conducting body itself. A perfect conductor in this sense is, however, unknown; the metals which are the best conductors, suffer certain effects, which bear some constant ratio to the quantity of Electricity transmitted, and to the quantity of metallic surface along which it passes. The first and most obvious of these effects, is the developement of Caloric. Thus wires are heated, or even fused, by the Voltaic as by the Electric discharge. So far this is only a Physical operation; but when the discharge is very powerful, the metals undergo combustion, and are oxidated. Now whether this Oxidation be simply the effect of their Elevation of Temperature in a medium affording Oxygen, so that the same effect in kind and quantity would be produced by an equal intensity of Heat howsoever excited; or whether the Heat evolved during the Electrical Transit be at all more favourable to this Chemical combination, by adding a sort of determining force, no experiments have yet ascertained.

We might, therefore, at present, be justified in regarding the burning of metals by Galvanism, merely as a case of Chemical combustion arising out of the ordinary Physical application of Heat to a combustible body. The most powerful Battery that has ever been constructed for the fusion and combustion of metals, is that of Mr. Children, with which most splendid results were obtained. The description of this instrument and its powers may be seen in the *Phil. Trans.* (f.)

Appropriate  
Batteries.

(33.) The conditions upon which the ignition or combustion of metallic wires depends, are totally different from those which influence Chemical decompositions. It is generally understood that in the Voltaic Battery the Intensity of the Electricity depends upon the number of plates; and that the Quantity evolved depends upon the superficial magnitude of the plates. Chemical decompositions, as we have already remarked, depend upon Intensity of action, and, therefore, require a great number of plates which may be very small; but the Calorimotive effect upon metals, seems to arise from Quantity; and, therefore, for these last-mentioned purposes, the number of the plates is not so important as their magnitude. And as in these cases it is desirable that the Electricity should be evolved with great rapidity, the charge of dilute Acid may be advantageously employed of a greater strength than is required for Che-

mical purposes. All this is stated as fact deducible from experiment, without reference to any particular Theory of the action of the Pile.

Part I.

(34.) It is a curious and important inquiry to ascertain the ratio which the number and superficial extent of the plates in a Battery, bear towards the effects of different kinds produced by that Battery. On this subject the following remarks by Sir H. Davy, are important. "MM. Gay Lussac and Thenard have announced that the power of Chemical decomposition increases only as the cube root of the number of plates; but their experiments were made with parts of Piles of a construction very unfavourable for gaining accurate results; and in various trials, made with great care in the Laboratory of the Royal Institution, the results were altogether different. The Batteries employed were parts of the great combination, carefully insulated, and similarly charged; arcs of Zinc and Silver presenting equal surfaces, and arranged in equal glasses filled with the same kind of fluid, were likewise used; and the tubes for collecting the Gases were precisely similar, and filled with the same solution of potassa. In these experiments, ten pairs of plates produced fifteen measures of Gas; twenty pairs in the same time produced forty-nine; again, ten pairs produced five measures; forty pairs, in the same time, produced seventy-eight measures. In experiments made with arcs, and which appeared unexceptionable, four pairs produced one measure of Gas; twelve pairs, in the same time, produced 9.7 of Gas; six pairs produced one measure of Gas; thirty pairs, under like circumstances, produced 24.5 measures; and these quantities are nearly as the squares of the numbers.

Ratio of  
Powers.

"It would appear from the experiments of Van Marum and Pfaff, confirmed by those of Messrs. Wilkinson, Cuthbertson, and Singer, that the increase of power of Batteries, the plates of which have equal surfaces, is as the number. I found that ten double plates, each having a surface of a hundred square inches, ignited two inches of Platina in wire of one-eightieth of an inch; twenty plates, five inches; forty plates eleven inches; but the results of experiments on higher numbers were not satisfactory; for one hundred double plates, of thirty-two square inches each, ignited three inches of Platina wire of one-seventieth, and one thousand only ignited thirteen inches, and the charges of dilute Acid were similar in both cases.

"The power of ignition for equal numbers of plates, seems to increase in a very high ratio with the increase of surface, probably higher than even the square; for twenty double plates, containing each two square feet, did not ignite one-sixteenth as much wire as twenty containing each eight square feet, the acid employed being of the same strength in both cases.

"Numerous circumstances are opposed to the accuracy of experiments made with high numbers or very large surfaces; the activity of combinations rapidly diminishes, in consequence of the decomposition of the menstruum used; and this decomposition is much more violent, the greater the number and surface of the alternations; the vapour rising likewise, when the action is intense, interferes by its conducting power, and the Gas by its want of conducting power; and when series containing above five hundred double plates are used, unless the insulation is very perfect, there is a considerable loss of Electricity; thus the great Battery of two thousand double plates belonging to the Royal Institution will



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scarcely act by its true Poles, when arranged on a floor of stone, and requires not merely the insulation of porcelain, but likewise of dry wood; and when arranged on a stone floor, it is hardly possible to walk near any of the approaching series without receiving shocks. In cases of the ignition of wire, the cooling influence of the substances in contact, and of that part of the chain not ignited, interferes most when small quantities of wire are employed, and with feeble powers; and hence the effect is at first in a lower, and then in a higher ratio than the number, when the whole range is small, as in the experiments above stated. If there is an imperfect connection in any of the series, a great diminution of power is the consequence. If one plate is corroded or covered with more oxide than the rest, there is a general loss of effect. If copper is substituted for Zinc, or Zinc for Copper, in a single series the result is similar; and I find that a Platina wire, introduced in the place of an arc of Silver and Zinc, in a series of thirty, diminished its power of producing Gas so much, that it was equal only to that of four." (g.) Consult also references (h.)

(35.) To examine the different Theories which have been proposed in order to account for the origin of those Phenomena which are termed Galvanic or Voltaic, falls not strictly within the scope of this Treatise. It may, however, be necessary for us to state in what manner it seems connected with Chemical Affinity, especially as some have supposed all Chemical Affinities to spring from Electrical action; whilst others, on the contrary, have asserted that all Electrical Phenomena are essentially accompanied by Chemical changes, thus referring those Phenomena to the mutations which take place among the Elementary molecules of Bodies. Whether the Electrical Polarities of the molecules of matter be or be not the cause of Chemical Affinity, is a question which the Chemist is deeply interested in resolving.

Volta, who laboured assiduously and successfully in this field, supposed that Electricity was developed solely by the contact of dissimilar metals. The fluid with which the Pile is charged, he regarded only in the light of a conductor. It seems true that the mere contact of two metals is sufficient for the evolution of Electricity; for if a plate of Copper and a plate of Zinc be made to touch each other, both being affixed to insulating handles, the Copper, after their separation, is found charged with resinous, and the Zinc with vitreous Electricity. The same, however, has been recently found to take place with two discs of the same metal when they are of different temperatures before their contact. In these cases no Chemical change is apparent; though it is possible, and even probable, that some oxidation may take place to a slight extent. In this Theory of Volta all the Chemical changes which manifestly attend the Electrical action, are, as causes, disregarded.

Dr. Wollaston became the most direct opponent of the views of Volta, and in an admirable Memoir, published in the *Philosophical Transactions* for 1801, he advanced numerous arguments in support of a contrary explanation of the case. The substance of Dr. Wollaston's Theory consists in supposing the Chemical change to be the primary action; as, for instance, the oxidation of the Zinc, where plates of Zinc and Copper are employed; and that the development of Electricity is a consequence resulting from thence.

The Theory of Sir H. Davy, which is now more generally received, acknowledges both sorts of action

already noticed. It admits the disturbance of the natural Electricities upon the contact and subsequent separation of dissimilar bodies, and does not consider that a Chemical change is essential to the commencement of Electrical action. But it was proved by experiment, that for the continuance and accumulation of Electrical action, Chemical changes in the Elements of the Pile are indispensable. Sir H. Davy traces this mixed operation by supposing that by the contact of the Zinc and Copper plates in the Pile, all the former become Positive, and all the latter Negative; that by means of the conducting fluid interposed, all the vitreous Electricity is enabled to accumulate at one end of the Pile, and all the resinous fluid at the other. Such is the primary and momentary action; but to produce a repetition of these effects, so as to promote the continuous action of the Pile, he considers the Chemical change as perpetually tending to restore the Electric equilibrium that has been thus disturbed. This takes place by the Electronegative Elements, Oxygen, Acids, &c. passing to the Zinc plate, while the Electropositive Elements, the Bases, Hydrogen, &c. go to the Copper surface, restoring, momentarily, the Electric equilibrium in both cases, and thus preparing the metals for a new effort of the Electromotive force. On these points consult references (i.)

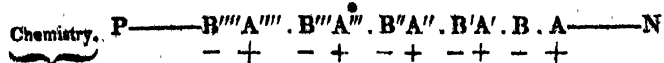
(36.) Whatever Theory be adopted with regard to the primary development of Electrical Action in the Pile, it becomes a matter of convenience to form some system which may unite in one view the effects as such; in order that we may employ it as a practical assistant in submitting bodies to Voltaic Electricity as a Chemical Agent. For this end it is quite immaterial which of the Theories already mentioned be admitted. In fact, the explanation which we are about to recite is to be considered not as an assertion of the actual laws which govern the molecular Affinities of substances, but only as a convenient mode of representation, a sort of illustration; it may be the true one in its most strict sense, or it may not; but in either case we may safely employ it as a law by which to regulate the methods, and foretell the results of our experiments.

Of such explanations the most clear was given by Grotthus, and first published in Italy. We subjoin the substance of it, as given in M. Thenard's Work, though it is almost *verbatim* the same with that of the original author as republished in the *Annales de Chimie*, (k.) because it gains an additional authority from having passed through the hands of that able Systematist. (k.)

If we place between the two Polar wires of a Pile in activity, any substance which is capable of undergoing decomposition by that Pile, immediately all the elementary molecules in each compound atom placed between the Positive and Negative Poles, undergo Polarization; that is to say, their natural Electric fluid is decomposed, and some of the Elementary molecules becoming Positive, tend towards the Negative Pole; while others becoming Negative, tend towards the Positive Pole. Suppose there to be only five compound Atoms between the two Poles, and that each Atom should be composed of two Elementary molecules; let A represent the Positive molecule and B the Negative molecule in the first Compound Atom; also let A' be the Positive molecule, and B' the Negative molecule in the second Compound Atom, and so on; the arrangement which will then result is shown in the following diagram:

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Modus operandi.



where P represents the Positive, and N the Negative Pole of the Battery. But the Negative wire attracting all the molecules marked A, and repelling all those marked B; and the Positive wire attracting, on the contrary, all those marked B, and repelling all those marked A; it will follow that all those marked A will arrive in succession at the Pole N, and all those marked B will simultaneously proceed to the Pole P; but in this transfer each Negative molecule will only become free after having combined itself momentarily with each positive molecule in succession, as it meets them on its passage; and reciprocally each molecule Positively excited will momentarily combine itself with each molecule that is Negatively excited, as it may come in contact with them. For example, the molecule B, on quitting the molecule A, will combine with the molecule A', then it will abandon this to combine with A'', from which it will again separate to unite with A''', and thus it will arrive at the Positive Pole, where, being disengaged from combination, it will appear with all its characteristic properties. The same will happen to every other molecule in our diagram, so that the molecule A''', on quitting the molecule B''', will unite with B'', and so on; hence, ultimately, the molecules A''' and B, acted upon in opposite directions by two equal forces, will combine at an equal distance from the two Poles.

Suppose, now, that instead of five compound atoms between the two Poles, there were an infinite number; it is evident that as they come within the influence of the fluid, they will undergo decomposition, and will be replaced by others, so that thus we may decompose any given quantity of the substance, so long as the Pile continues to be in action.

To render this Theory more clear, let us apply it to the decomposition of water. Water is a compound of two substances, which, when free, are with us in the gaseous state; and which have received the names of Oxygen and Hydrogen. If we submit this liquid to the action of the Pile, the Oxygen will develop itself at the extremity of the Positive wire, and the Hydrogen at that of the Negative one. The atoms of water are Polarized so that their molecules of Oxygen become Negative, and their atoms of Hydrogen become Positive; the former then are represented in our diagram by the letters A, A', &c. and the latter by B, B', &c. But as Hydrogen scarcely combines with any metal, while Oxygen combines readily with all except Gold, Platinum, and a few others, forming with them solid substances: consequently Hydrogen will, in almost all cases, disengage itself in the gaseous state at the extremity of the Negative wire; and Oxygen will only disengage itself in the same state at the extremity of the Positive wire, when that wire is coated of Gold, Platinum, &c. These Gases may easily be collected either together or separately, by methods pointed out in our Treatise on GALVANISM.

If the Pile be powerful, and especially if the water contains a little salt, or rather a little free Acid, by which its conducting power is much increased, we may perceive vivid effluence at the extremity of each wire.

It is obvious from what has now been advanced, that the decomposition of a substance by the Pile, depends upon the ratio existing between the reciprocal Affinity of the constituents of the substance and the property that they possess of placing themselves in conditions of greater or less opposite Electrical intensities; and that,

consequently, it is possible for substances to exist which the Pile is capable of decomposing, although united by a very strong Chemical Affinity; and that, on the contrary, there may be others which it cannot decompose, though the Chemical Affinities are not powerful. Hence we perceive the great importance of knowing the powers which substances possess of becoming more or less Positive with reference to each other. This point is, however, as yet in a state of great uncertainty: M. Berzelius has given a Table of the Electrochemical relations of the Elementary bodies, but we fear that it is too imperfect to be of much practical utility, and, therefore, we do not transcribe it in this place. (2.)

#### § 4. Chemical Agency of Magnetism.

(37.) The agencies of Magnetic influence in aiding or in impeding Chemical Affinities have as yet been recognised to only a very slight extent. And yet these two species of action are not quite independent of each other; some substances are sensible of Magnetic power, others not so. Among the metals some are capable of permanent Magnetism, others are only capable of a temporary Magnetic state induced by Electricity. Iron when present even in a small proportion, renders the mass containing it attractable by the Magnet. The same property is continued to it even in its lowest degree of oxidation, but in the higher stages of oxidation it loses this property. Pure metallic Nickel, Cobalt, Manganese, and Chromium, are all attracted by the Magnet. But with these a small admixture of Arsenic is fatal to the property.

(38.) The permanency of Magnetism is also sometimes greatly affected by the Chemical constitution of the body: thus, pure soft Iron soon loses any Magnetic power that may be communicated to it: but the presence of that small proportion of carbon which converts Iron into Steel, renders it capable of retaining permanent Magnetism even for many years.

(39.) Berzelius relates (*m.*) that Hansteen and Maschmann placed a solution of Silver in a Syphon-shaped tube that the Silver might be reduced by metallic Mercury; and that they always found that when the two legs of the tube stood in the plane of the Magnetic meridian, the Silver in the Northern leg shot out into more numerous and better formed crystals, than in the Southern leg; where, in fact, the reduced Silver immediately mingled with the Mercury. Upon placing the legs of the tube due East and West, the process of reduction went on much more slowly and the reduced metal stood at an equal height in both legs. Murray made an experiment of the same sort in which he placed iron wire in a weak solution of Silver. So long as the Iron wire had no Magnetic Polarity no Silver was reduced, but as soon as a Magnet was placed near it the reduction commenced. He also found the reduction most considerable at the North Pole of the wire, which is in accord with the experiments of Hansteen and Maschmann.

(40.) Lüddecke placed over the two Poles of a horse-shoe Magnet a glass vessel containing saline solutions of such concentration as to crystallize in a few hours' time. He employed Acetate of Lead, Muriate of Ammonia, or Proto-Sulphate of Iron. When crystallization had taken place, it appeared that there was a clear round space left vacant between the two Poles where the Magnetic force was strongest; though the rest of

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Such is the scanty display of facts which we are able to produce in connection with this branch of our subject, but we think they are sufficient to show that Magnetic action does exert some influence on molecular attraction.

References from (22.) to (40.) inclusive.

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Part II.

## PART II.

### CHAPTER I.—General Physical Properties of Ponderable Matter.

(41.) THE Properties of Matter which we profess to examine in this Treatise are those that are strictly Chemical. But it must not thence be inferred that we have no business with the Physical Properties of bodies, for several of those marks by which a Chemist distinguishes one substance from another are, strictly speaking, Physical Properties. Such as Hardness, Specific Gravity, Elasticity, Colour, &c. To investigate all these fully is a part of the province of General Physics, and several of these properties form the basis of all Mechanical Science. In this preliminary introduction we shall as briefly as possible mention those Properties which are essential to the understanding of future Sections, entering at the same time rather more fully upon such details as form a portion of the operations of practical Chemistry.

Physical Properties

(42.) *Magnitude* is a Property belonging to all substances, and need not be made more intelligible by verbal definitions: let it only be remembered that it refers to space alone. *Magnitude* may be Linear, Superficial, or Solid; in which latter case it is usually spoken of under the term *Volume*. *Divisibility* is a Property of Matter having reference to *Magnitude*. Mathematically speaking, Matter is divisible *ad infinitum*, but the practical or mechanical divisibility of Matter is limited by our powers of handling or viewing minute objects. Hence it is that the Chemical divisibility of Matter greatly exceeds that which can be effected mechanically: for by dissolving a solid substance in any appropriate menstruum we may very greatly dilute the solution, and still be able to prove by reagents that every portion of the solution, however minute, contains also some portion of the original Solid. The limit to this also seems to be fixed by the powers of our organs

of vision, &c. But in this case the extreme minuteness of that portion of solid matter which has been separated from the original mass, and thus indirectly again recognised, almost surpasses our conception.

That Property of Matter about which much has been written under the name of *Impenetrability of parts*, is, in fact, the same thing as the Property of being touched and felt, by which we are convinced of the existence of substances. Generally speaking, two substances cannot exist in the same space, and this is all that is meant by the property of *Impenetrability*; but the existence of the Property itself, speaking with mathematical rigour of Matter in its natural state, seems to be at least doubtful. It is supposed that no substance is absolutely solid, and the experiments with metallic alloys, in which great condensation frequently takes place, as well as the solution of solid masses of metals or salts in liquid menstria, without proportionably adding to the volume of the mass, goes far to support the mathematical view of the case. *Impenetrability* exists if we speak of any one given substance only, and it must exist with reference to all Matter if we possessed it in an absolutely solid state; but as this is never the case, we cannot assert it of all heterogeneous bodies with reference to each other.

It would appear that all substances are *Compressible*; some to a great extent, as the Aëriform Fluids; some scarcely at all, as the Liquids and Solids.

*Elasticity* is also a term of frequent occurrence among the Physical Properties of bodies: it is defined to be that Property by which bodies that undergo compression return to their former state upon the removal of that pressure. It has not been so done, but some limitation ought to be made, as to the manner in which

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that pressure is applied, for the Elasticity of air confined within a vessel is of one kind; and the Elasticity of a billiard ball is of a totally different kind. The former is the tendency of a substance which by a force impressed has been compelled to admit of a closer approximation among its molecules: to return to its original volume, due to its condition at the beginning of the experiment. The latter is the tendency of a body to resume its original form: that form having been changed by an external force, so applied that the molecules have had to change their position with reference to each other, but it is not essential that the actual volume of the substance should have been diminished, though it is true in most cases of Elasticity that condensation is more or less present.

State of Aggregation.

(43.) The *State of Aggregation* in which all bodies exist, is either *Solid*, *Liquid*, or *Aeriform*: the two latter are both comprised under the general term *Fluid*. As these states are Physically different, so are the effects produced upon them by the operations of various Physical agents.

*Solids* may be defined to be those substances the integrant molecules of which adhere together with such tenacity, that between them no relative motion nor separation takes place without the operation of some considerable extrinsic force impressed. The extreme measure of this innate adhesion is the limit which is sufficient for the substance's preserving its solid form when left to itself, be that form what it may.

*Fluids*, on the contrary, have so slight a cohesive force existing between their particles that they easily move relatively to each other, and cannot, if left to themselves, preserve any form, but are contained in vessels formed of solid matter for their support.

It is obvious that these two states, the Solid and the Fluid, may pass gradually into each other; and the freedom of motion among the particles is the limit at which the solid state ends and the fluid one commences. For example, if a mass of Lead be taken, it is at first a solid, but, if it be sufficiently heated, the particles acquire the power of moving among themselves with such facility upon the impression of any slight force, that the fluid state commences and the Lead becomes a liquid.

The aeriform substances agree in all the Properties hitherto attributed to liquids: they are strictly fluid, and enjoy this property in a higher degree than the Liquids; but they possess also this remarkable one in addition; viz. that their molecules are repulsive of each other, to any extent at which they have hitherto been tried. The aeriform fluids require to be confined in vessels of solid matter; but whatever be the magnitude of the vessel, the idiorepulsive forces of the molecules enable them to extend themselves equally throughout all the space contained within the vessel.

(44.) We are able, by various means, to make many substances pass through each of these states, the Solid, the Liquid, and the Fluid, in succession. Thus Ice, by the application of Heat, passes from the solid to the fluid state, and by an increased action of the same Physical agent, the water passes to the aeriform state, becoming Steam. Reasoning upon Analogy we may conclude that all substances in Nature are capable of existing in each of these three forms, but there are few substances which our means are sufficiently powerful for us so to exhibit. Some Solids we are unable to fuse, that is, to reduce to the form of Liquids; but as the

means of producing intense Heat have been increased, this number has been gradually diminished. Many of these, however, our means do not enable us to volatilize, though we have just reason for supposing that the defect lies in our powers, and not in the natural capacities of the bodies.

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Heat is the principal Physical Agent by which these changes are effected, but it is not the only one, for Chemical Affinity can produce an analogous operation. Thus when two substances, existing in different mechanical states, combine together, the resulting body is of the one state or the other: in which case one of the two yields up its original condition to the laws which regulate the existence of the other substance. For example, Silica, which in its pure state is a solid, unites with Fluoric Acid, and becomes an invisible constituent part of a Gas; a term given by Van Helmont to aeriform fluids and still much employed by Chemists to designate all such that are not vapours, Atmospheric Air excepted. Oxygen Gas unites with Metals, and thus becomes a Solid. In other cases both substances change their condition; thus Oxygen Gas and Hydrogen Gas unite, and form the Liquid, Water; Ammoniacal Gas and Muriatic Acid Gas unite to form a solid substance, the Muriate of Ammonia.

(45.) It has been supposed by many Philosophers, that the state of aggregation of bodies depends upon the resultant of two opposite forces, the one an attractive one, inherent in the molecules of matter, the other a repulsive one, due to the operation of combined caloric. And, further, that a body is solid when the attractive force surpasses the repulsive one, liquid when both are in equilibrium, and aeriform when the repulsive one is the more powerful of the two.

(46.) We find in all bodies a tendency to fall to the ground, or, in fact, towards the centre of the Earth; the measure of this tendency, or force, is called the *Weight* of the body. In various masses taken from the same substance, the Weight is in direct proportion to the volume of the body. But as it is obvious to all, that in masses taken from different substances, the Weight of a given volume of one differs greatly from the Weight of an equal volume of another, it is convenient to have some mode of expressing this difference.

For this purpose let it be supposed, that we had a Specific Table exhibiting the Weights of some given volume of all substances known; and, further, let the number expressing the Weight of any one of these be made the unit of the scale; then calling this one, and reducing all the other numbers, so that they bear the same proportion to unity, which their true Weights for the given volume bear to the true Weight of the given volume of the substance adopted for the standard, we arrive at what is called the *Table of Specific Gravities*: that is to say, a Table of the proportionate tendencies of substances to the Earth without reference to their quantity or magnitude. Solid Bodies and Liquids are usually referred to water as the unit of their Specific Gravity, but to this subject we shall return hereafter.

(47.) It must be obvious that, as this tendency of bodies to the Centre of the Earth is a part of the universal law of Attraction, the Weight of a given mass of any substance must change if estimated at different distances from the centre of force. Thus in consequence of the spheroidal figure of the Earth, bodies weigh less at the Equator than they do at the Poles;

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(48.) In matters of great delicacy when Solids are concerned, and in all cases when aeriform matter is in question, the Specific Gravities of bodies are supposed to be taken *in vacuo*; and at some given temperature; as, otherwise, the dilatations or contractions produced by Heat would greatly interfere with uniformity of result.

Proceeding upon these principles; if  $W$  be the Weight of any mass of matter,  $S$  its Specific Gravity,  $g$  the force of Gravity at the latitude in which the experiments are made, and  $W'$  the Weight of an equal volume of water, at the standard temperature which in England is usually taken at 60° Fahrenheit, or sometimes 62° Fahrenheit,

$$W = g W' S.$$

Here it is to be remarked, that  $W$ ,  $W'$ ,  $S$ , and  $g$ , are not absolute quantities, but abstract numbers, each referring to some assumed unit.

In France, it is usual to adopt for the standard Temperature that at which water has its maximum density; and from the constitution of the French System of Weights and Measures, the *Gramme* Weight consists of one cubic *Centimetre* of Distilled Water at that temperature. If therefore  $V$  be the number of cubic *Centimetres* in the mass,  $V$  is also the Weight in *grammes* of the volume of water equal to that of the substance. And  $V S$  becomes the actual Weight of the same volume of any other substance whose Specific Gravity is  $S$ .

Should it be required to find the value of  $W'$  for any given volume of water;  $W' = 252,158 V$  Troy Grains; Thermometer 62° Fahrenheit; Barometer 30 inches; where  $V$  refers to English Cubic Inches: because at that Temperature and Pressure, one Cubic Inch of Distilled Water weighs 252,458 Troy Grains, according to the latest examination.

(49.) The following General Theorems are of constant service to the practical Chemist.

Let  $W$  be Weight,  $V$  Volume, and  $S$  Specific Gravity.

Then, generally,  $W \propto V S$ ,

$$\therefore S \propto \frac{W}{V}, \text{ and } V \propto \frac{W}{S}.$$

Let there be two substances mixed, or combined, providing only that no condensation take place.

Let  $W_m$ ,  $W_d$ , and  $W_l$  be the Weights of the mixture, the denser, and the lighter bodies respectively.

Also let  $S_m$ ,  $S_d$ , and  $S_l$  be their Specific Gravities respectively.

And  $V_m$ ,  $V_d$ , and  $V_l$  their volumes respectively.

$$(50.) \text{ Then } S_m = \frac{W_d + W_l}{V_d + V_l}.$$

$$(51.) \text{ Or } = \frac{W_d + W_l}{W_d S_d + W_l S_l} \cdot S_d S_l$$

which is the usual formula, but in practice it is more conveniently represented thus

$$S_m = (W_d + W_l) \div \left( \frac{W_d}{S_d} + \frac{W_l}{S_l} \right).$$

$$(52.) \text{ Also } V_d = \frac{S_m - S_l}{S_d - S_l} \cdot V_m$$

$$(53.) \text{ And } V_l = \frac{S_d - S_m}{S_d - S_l} \cdot V_m$$

$$(54.) \text{ Also } S_d = \frac{S_m V_m - S_l V_l}{V_d}$$

$$(55.) \text{ And } S_l = \frac{S_m V_m - S_d V_d}{V_l}$$

(56.) If these formulæ be applied to the case of Atmospheric Air,  $S_m$  becomes = 1, because in all questions relating to aeriform bodies, the Specific Gravity of Atmospheric Air is made the unit of the scale to which  $S_l$  and  $S_d$  are referred. From all the above formulæ  $g$  has disappeared, because it is usual to consider the force of Gravity unity.

(57.) These things being premised, we need only advert to one other Property of Matter which also is general in its effects, or operations. It is this, that whether matter exist in the solid, the liquid, or the gaseous form, it dilates by the application of Heat, and contracts when Caloric is abstracted. By this property the Solids are least affected, the Liquids rather more so, and the aeriform substances possess this Property to a very great extent. From their Physical constitution it is obvious that this must be the case; for since the molecules of all Gases and vapours are in so active a state of mutual repulsion, that their volume at all times depends upon the pressure to which they are subject, if we suppose an equilibrium between that pressure and the elastic force of the Gas, any accession of Caloric, which, as is well known, increases the repulsive force, will enable the aeriform Fluid to expand itself, and to occupy a larger volume.

The case of water, which has its maximum density at 40° Fahrenheit, and of those metals which expand during the act of solidification, does not justly form an exception, for all these effects are dependant upon a new arrangement of the molecules which takes place during the process of crystallization.

(58.) It may be convenient to note the general formulæ for the expansions of all bodies by accessions of temperature.

Let  $V'$  be the volume at any temperature  $t'$ ; and  $V''$  be the volume at temperature  $t''$ ; where  $t'$  and  $t''$  are counted from the point of melting ice. Also let  $K$  be the true cubic dilatation for each unit of volume, (in terms of  $V$ ), and for each degree of the thermometer to which  $t$  refers.

$$\text{Thus, generally, (HEAT, 35.) } V'' = V' \cdot \frac{1 + K t''}{1 + K t'}$$

which formula applies to Solids, Liquids, or Gases.

(59.) But since in some Tables of dilatations the linear dilatations only are given, let this =  $k$ , then in this case,

$$V'' = V' \cdot \frac{1 + 3 k t'' + 3 k^2 t''^2 + k^3 t''^3}{1 + 3 k t' + 3 k^2 t'^2 + k^3 t'^3}$$

(60.) And it has been shown (HEAT, 35.) that in Solids where at a distance from their fusing points the dilatation is very small, we may make  $K = 3 k$ , and employ the formula in Art. (58.); or as a still more simple, though less rigorous, expression, we may use this

$$V'' = V' \{ 1 + K (t'' - t') \}.$$

Chemistry.

Solids only.

*Properties that belong to Solids exclusively.*

(61.) There are several of the Physical properties of Solid Bodies, which, though not strictly Chemical, afford valuable assistance to the Chemist: such are *Brittleness*, a property too well known to need description: *Ductility*, or the power of being drawn out into wires: *Malleability*, the capacity for being beaten out into thin Laminæ. Gold is the most malleable of metals, and it is also extremely ductile, but these properties do not uniformly accompany each other, for Iron is tolerably ductile, but malleable only to a very slight extent. *Tenacity* depends upon the cohesive force with which the molecules of a solid adhere together. Many experiments have been made on this subject chiefly referring to the metals. Their Tenacity has been estimated, by ascertaining what is the utmost weight that a wire of given diameter will be able to sustain without being broken. The *Hardness* of Solids differs greatly, and is frequently used as a test, especially in Mineralogical researches. The *Fusibility* of those Solids that we are able to melt by heat differs considerably. *Vide Treatise on HEAT*, Art. (65.) and Table IV. Appendix. The *Volatility* of substances frequently serves as an auxiliary property for separating one substance from another in Chemical Processes, as this property differs, in extent for different substances. The *Compressibility* of Solids exists, though it is scarcely used as a mark of recognition; for the Specific Gravity of metals is increased by their being hammered. *Elasticity* and *Sonorousness* are other existent Properties that need only to be named. The *Texture* of Solids, or the mode in which their Elementary Molecules are united to each other, is a subject of great intricacy, but is one which at times falls under the Chemist's examination: as, for instance, in the experiments made by Messrs. Stodart and Faraday upon the metallic alloys, by submitting them to the action of dilute acids. The *Structure* of Solids refers more particularly to Crystalline Bodies, and may be described as that species of texture which results from the aggregation of the variously formed integrant molecules of the Crystal. *Crystalline Form* is also an important feature in the description of many Solids, such as the Metals, Salts, and native Minerals, but its study forms an independent branch of Mathematical Science. The *Specific Gravity* is, of all others, that property which affords the readiest, and frequently the most decisive, Physical indication of the nature of a solid substance.

(62.) From the explanation already given of the nature of Specific Gravity, Art. (46) the rationale of the means employed for ascertaining the Specific Gravity of Solid Bodies will be very apparent. The substance is first weighed in air, and then in water. The apparent loss of weight by the latter process is equal to the weight of the volume of water displaced by the presence of the solid.

Let  $W_a$  be the weight in air, and  $W_w$  the decrement of weight from the immersion; i. e. the weight lost.

$$\text{Then the Specific Gravity } S = \frac{W_a}{W_w}.$$

Strictly speaking, the first weighing should take place in vacuo, and the temperature of the Bodies, especially the water, should be 62° Fahrenheit, the Barometer standing at 30 inches. The instruments employed are either the Hydrostatic Balance of Nicholson, or a

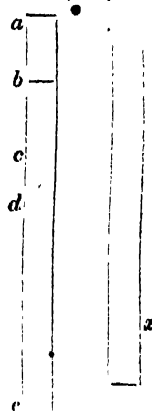
delicate Balance of the common construction; in which case the substance to be weighed is suspended by a hair from one of the arms, and thus immersed in the water.

(63.) When it is required to find the Specific Gravity of a Salt or other substance that is soluble in water, the usual process may be followed by using instead of water, oil or alcohol, or any Liquid of known Specific Gravity, in which the substance is not soluble. In this case the process affords the Specific Gravity of the substance, referred to that of the Liquid in which it has been weighed, and as the Specific Gravity of this Liquid is known with reference to water, the Specific Gravity of the Solid is easily calculated from these ratios.

(64.) Various methods have been devised for obtaining the Specific Gravity of Substances in the state of Powder; of these the following is much the best. It was originally proposed by M. Say in the *Annales de Chimie*, tom. xxiii. p. 1; but the following description is given of the instrument as employed by Professor Leslie, in the *Annals of Philosophy* for April 1826.

"The instrument consists of a glass tube, *a c*, about three feet long, open at both ends.

The wide part, *a b*, is about  $\frac{1}{10}$  of an inch in diameter, the part *b c* about  $\frac{1}{30}$ . The two parts communicate at *b* by an extremely fine slit, which suffers air to pass, but retains sand or powder. The mouth at *a* is ground smooth, and can be shut so as to be air-tight by a small glass plate shown a little above it in the figure. The substance whose Specific Gravity we wish to find, suppose it to be sand, is put into the wide part of the tube, *a b*, which may either be filled to the top or not. The tube being then held in a vertical position, the narrow part is immersed in an open tube or vessel, *x*, filled with mercury, till the mercury rises to the gorge at *b*. The lid is then fitted on air-tight at *a*. In this state it is evident that there is no air in the tube except what is mixed with the sand in the cavity *a b*. Now suppose the Barometer at the time to stand at 30 inches, and that the tube be lifted perpendicularly upwards till the mercury stands in the inside of *b c* at a point *c*, 15 inches above its surface in the open vessel *x*. Had the Barometer stood at 29 inches, the height must have been 14½ inches, and so on; which may be regulated by a scale. It is evident, then, that the air in the inside of the tube is subjected to a pressure of exactly half an atmosphere, and of course it dilates and fills precisely twice the space it originally occupied. It follows, too, that since the air is dilated to twice its bulk, the cavity *a b* contains just half of what it did at first, and the cavity *b c* now containing the other half, the quantity of air in each of these parts of the tube is equal. In other words, the quantity of air in *b c* is exactly equal to what is mixed with the sand in *a b*, and occupies precisely the same space which the whole occupied before its dilatation. Let us now suppose the sand to be taken out, and the same experiment repeated, but with this difference, that the cavity *a b* is filled with air only. It is obvious, that, as the quantity of air is greater than it was when part of the cavity was filled with sand, it will, when dilated to double the bulk, under a pressure



**Chemistry.** of 15 inches, occupy a larger space than in the other experiment, and the mercury will only rise, let us suppose to *d*. But let it be remembered that the attenuated air in the narrow tube always occupies exactly the space which the whole occupied under the ordinary atmospheric pressure. Now this space is in the one case the cavity *b c*, and in the other *b d*. Hence it clearly follows, that the cavity *c d*, which is the difference between these, is equal to the bulk of the solid matter in the sand. Now by marking the number of grains of water held by the narrow tube *b c* on a graduated scale attached to it, we can find at once what is the weight of a quantity of water equal in bulk to the solid matter in the sand, and by comparing this with the weight of the sand in air, we have its true Specific Gravity.

"As some porous bodies, such as Charcoal, hold much condensed air within their pores, and may, probably, retain this property in some degree even when in powder, the chance of error arising from this source is obviated by comparing the dilatation which takes place under different degrees of pressure—under 10 inches and 20, for instance, or under  $7\frac{1}{2}$  and 15.

"The Specific Gravity of Charcoal is generally estimated as under 5, but by this process the powder of Charcoal exceeds that of the Diamond. The Specific Gravity of Mahogany is 1.06, but of Mahogany sawdust 1.68. That of Wheat flour 1.56, and of pounded Sugar 1.82. Of Salt 2.15, agreeing with the common estimate. Volcanic ashes 4.4, being equal to that of some metallic ores."

**Corrections.** (65.) Should it be necessary to introduce these very minute corrections, which depend upon the temperature of the substances or liquids employed, the formulæ for this purpose may be seen in M. Biot's *Physique*, vol. i. p. 426, though we cannot devote the space requisite for their introduction into this Treatise.

**Solids absorb Gases.** (66.) Substances which are usually called Solid, but which like Charcoal contain numerous pores, are capable of condensing within those pores very considerable quantities of Gases: but to this property we shall advert when we have entered more fully upon the description of aeriform fluids.

#### *Properties that belong to Liquids.*

**Liquids.** (67.) Of the extensive catalogue of Properties that has been recited as belonging to Solid Bodies, few only will be found to apply to those Substances which exist in the Fluid State.

**Tenacity.** In *Tenacity* the Fluids may be said to differ slightly, as there is a difference in the magnitude of the drop that may be formed by each when falling from the mouth of a Phial: and the quantities which will issue from small orifices under given pressures are found to be variable. This circumstance, however, may also be explained by attributing to each different degrees of their characteristic Property Fluidity.

**Volatility.** Some Fluids are of easy *Volatility*; others are not volatile at all under any processes to which we can submit them; though analogy and experiment would unite in leading us to suppose that all substances in nature are capable of being rendered fluid, and of being also volatilized by the application of a sufficient degree of heat. *Vide Treatise on Heat*, Art. (65.) &c. And it is to be remembered, that in practice some substances, such as the fat oils, take fire, and are consumed upon a sufficient elevation of temperature: so that the universality of the law seems here to be interfered with by the

presence of another phenomenon. The exception is, however, only apparent, for the fat oils are capable of regular distillation in vacuo. **Part II.**

Circumstances connected with the evolution of **Ebullition.** vapour, and its passage through the fluid, produce the phenomenon of *Ebullition*. *Vide Treatise on Heat*, Art. (73.) &c. The temperature at which fluids boil, or pass into the state of vapour, frequently forms a part of the Chemist's researches, and ought always to be stated among the physical properties of every fluid.

(68.) For a long time it has been questioned whether liquids were compressible, and water was the substance upon which experiments were made. The Florentine Academicians were the first to devise a process which by its result seemed to prove that water was compressible to a slight extent: the researches of Professor Oersted and of Mr. Perkins have decided this point satisfactorily. By a pressure of 2000 atmospheres, Mr. Perkins reduced a mass of water to  $\frac{1}{3}$  of its original volume. **Compressibility of Fluids.**

(69.) As might be expected, the Specific Gravity of Liquids forms an important feature in their Physical History. Water is made the unit of the scale to which they are referred as in the case of solids. The mode usually employed for obtaining equal volumes of the two substances to be compared is very simple: the weight of the water, which is contained by a small bottle capable of being accurately closed, is compared with the weight of an equal volume of liquid obtained by filling and weighing the same bottle. **Specific Gravity of Liquids.**

Let  $W_w$  and  $W_l$  be the weights of the water and of the liquid respectively, then the Specific Gravity

$$S = \frac{W_l}{W_w}$$

And for greater simplicity, the small bottle or flask is sometimes made to hold exactly 1000 Grains of Distilled Water, and a constant counterpoise is provided for the empty bottle; so that when it is filled with any other liquid, the weight that is required in addition to the counterpoise to produce an equilibrium, represents at once the ratio borne by the liquid to 1000 grains of distilled water; or, in other words, the Specific Gravity of the Fluid.

(70.) It is evident, however, that the rule above given produces only an approximative result. For, in the first place, both the water and the fluid must be referred to some fixed standard of temperature, to obviate the effects of dilatation. In France, this standard point has been judiciously placed at the maximum density of water, which is about 40° Fahrenheit, but in this country 62° Fahrenheit is usually considered the standard point. In the next place, the dilatation of the bottle should be allowed for by calculation. The experiments also should be made in vacuo; or else reduced by calculation so as to obviate the errors arising from their being made in air and moisture. And lastly, the Barometric Pressure should not be overlooked.

It would be easy to insert formulæ which afford these corrections, but in practice they are seldom resorted to, and the limits to which we must here confine ourselves, only permit our referring those who may wish for further information on the subject to M. Biot's *Physique*, tom. i. p. 399.

(71.) We have already adduced in Art. (58.) a general formula applicable to the Dilatations of Liquids by the Effect of Caloric; but since it always happens **Dilatation of Liquids.**



**Chemistry.** that Liquids are contained in vessels formed from some material which is also affected by heat, though it may be in a greater or less degree, it becomes necessary that we should be able to compute the value of the apparent inaccuracy thus introduced. On this subject consult the *Treatise on Heat*, Art. (42.), whence we learn that if  $V$  be the volume of a fluid contained in any vessel at  $32^{\circ}$  Fahrenheit;  $V'$  the apparent volume that the Fluid in the same vessel assumes by being heated  $t^{\circ}$  above  $32^{\circ}$  Fahrenheit;  $\delta$  the true cubic dilatation due to  $t^{\circ}$  upon each unit of which  $V$  is a multiple; and  $K$  the cubic dilatation of the substance of the vessel for each degree to which  $t$  refers, expressed also in terms of that unit to which  $V$  and  $V'$  refer; that

$$\delta = \frac{V' - V}{V} + \frac{V' K t}{V},$$

where  $\frac{V' - V}{V}$  is the true dilatation of the fluid, and  $\frac{V' K t}{V}$  is the correction to be applied in consequence of the dilatation of the vessel.

Now let  $\theta$  be the true cubic dilatation of the contained fluid for each degree of the scale to which  $t$  refers, and the same being true for any other temperature  $t'$ , (above  $32^{\circ}$  Fahrenheit,) we have

$$\delta = t' \theta = \frac{V' - V}{V} + \frac{V' K t'}{V},$$

whence 
$$V' = V \cdot \frac{1 + t' \theta}{1 + t' K},$$

and, similarly, 
$$V'' = V \cdot \frac{1 + t'' \theta}{1 + t'' K},$$

$$\therefore V''' = V' \cdot \left\{ \frac{1 + t'' \theta}{1 + t'' K} \cdot \frac{1 + t' \theta}{1 + t' K} \right\},$$

which is independent of the volume at  $32^{\circ}$  Fahrenheit, and is true for any Liquid or Gas contained in any expansive vessel.

**Liquids absorb Gases.** (72.) Liquids have the power of absorbing Gases, and under the head of aeriform Fluids that property will be noticed.

#### Physical Properties of Aeriform Bodies.

**Aeriform bodies.** (73.) The properties which we have to record as belonging to aeriform fluids are, as might be anticipated, more nearly similar to those of liquids, than to those of solids. They are *Tenuity, Weight, Compressibility, and Elasticity*.

Aeriform bodies have frequently been divided into two classes: permanently elastic gases and vapours; the former comprising atmospheric air, and those gases which under all our ordinary operations at common temperatures are permanently elastic. The latter consisting of vapours produced from solids or liquids by the influence of caloric. It would seem, however, from the analogies presented by certain recent experiments, that the distinction between these two classes is rather formal than real. In short, that the difference, though confessedly well marked, depends solely upon those temperatures and pressures under which we live and make our experiments. For by the skill of Mr. Faraday, many of those gases which formerly were considered as permanently elastic have been exhibited under the liquid form.

There is, however, so great a practical difference

between the vapour of water, and of other fluids, which rises at so low a temperature as to be continually present in our experiments, and the vapour of pure carbon, which has only been undesignedly produced during the most intense heats, employed on a large scale, that for convenience we shall, in some degree, adhere to the old arrangement, and thus speak first of pure and dry gases, proceeding afterwards to the vapours.

To speak with strict precision, as far as our present knowledge permits, we may define both gases and vapours to be solid bases, united with such a portion of caloric as that the combination resulting exists in the aeriform state.

#### Pure dry Gases.

(74.) It would appear that a difference exists in the molecular constitution of gases, both from the difference of their specific gravities, their difference of *Tenuity* proved by the times that given volumes of each gas require for passing through orifices of given magnitude, and also from certain Chemical views arising out of the theory of Atoms. Mr. Faraday ascertained the times requisite for the escape of different gases from a vessel whence they issued through capillary tubes. The pressure at the outset of the experiment was the same in each case for all the gases, viz.  $1\frac{1}{2}$  atmosphere.

Carbonic Acid escaped in...	156'.5
Olefant Gas .....	135'.5
Common Air .....	128'.0
Coal Gas .....	100'.0
Hydrogen.....	57'.0

Under low pressures the differences are not so great; for in one such case a certain volume of olefant gas, and an equal one of hydrogen gas, issued in the same interval of time, the pressure being inconsiderable. Hydrogen gas, under the pressure of a small column of mercury, escaped through some very small orifices in one-third of the time that an equal volume of olefant gas did. The differences between the results of these experiments increased in proportion to the resistances opposed to the issuing of the fluids, whether these resistances arose from diminishing the diameter of the tubes, or from increasing their lengths. The proportionate times of escape did not vary in any ratio with the specific gravities of the gases. And the ratios expressing the issuing powers of different gases under the same pressure, did not bear any direct proportion to another corresponding set of numbers resulting from a similar experiment under a different pressure. (a.)

M. Girard subsequently made some experiments of a similar nature, on a large scale, from one of the gasometers for lighting Paris.

The comparison refers to common air and carburetted hydrogen, issuing from equal orifices, at equal distances from the gasometer, under the same pressure, and during a given time. The lengths of the pipes through which the airs passed were as the numbers 1288, 3758, and 6228; the quantities of atmospheric air issuing were as the numbers 902, 541, and 394, and of carburetted hydrogen as the numbers 1281, 710, and 541. M. Girard's paper is well worthy of attention. (b.)

(75.) The gases differ considerably from each other *Weight* in weight, that is in specific gravity. Thus we find our attention called to two problems, which frequently occur to the practical Chemist for solution. The one the determination of the absolute weight of a given volume of any gas under a given temperature and



Chemistry. pressure; and the other, the ratio of such weights for all the different gases, that is their specific gravities, referred to the weight of any one among them as a unit. For this purpose Atmospheric Air has been employed, calling its weight unity in the Series.

On the general principles of Specific Gravities, if we have the weight of a volume of dry gas and of an equal volume of dry atmospheric air, at a given temperature and pressure, the specific gravity of the gas equals the weight of the gas divided by the weight of the air. But before we enter upon the practical processes for obtaining the Specific Gravity of a Gas, we must become better acquainted with certain other properties of aeriform Fluids.

For the Specific Gravities of the gases see Table No. 1, and consult References (c.), (d.), (e.), (f.), (g.)

Compression and Elasticity.

(76.) A pure and dry gas is capable of being mechanically compressed when confined in a close vessel, and upon the removal of the pressure, the aeriform fluid returns to its original volume. And when air is confined in a bent tube and loaded with different weights of mercury, the spaces into which it is compressed are found to be inversely as those weights. But the weights are the measures of the elasticity, therefore the elasticity always varies directly as the space occupied by the air.

The density varies inversely as the space, and therefore the elasticity of air varies directly as its density. (Mariotte's law.)

Volume.

(77.) Hence if  $V$  be the original volume of a gas under a pressure  $p$ , (usually expressed in inches of mercury in the Barometer,) and  $V'$  its volume under a pressure  $p'$ ,

$$\frac{V}{V'} = \frac{p'}{p}, \quad \text{or } V = V' \frac{p'}{p}.$$

This formula is employed whenever we have the volume of a gas  $= V'$  under a known pressure  $p'$ , and wish to ascertain its volume under some other pressure  $p$ : in this case  $V$  is obtained from the above equation.

*Example.* Having 100 cubic inches of gas at Barometer 28, what is this equivalent to under the standard pressure of 30 inches?

Here  $V' = 100$   $p' = 28$  and  $p = 30$ ,

$$\therefore V = 100 \cdot \frac{28}{30} = \frac{2800}{30} = 93.333.$$

(78.) If the air or gas be confined in a tall jar or tube standing over mercury, so that the pressure cannot be naturally equal within and without the jar, and thence the air becomes dilated.

Let the length of the column of gas in the tube  $= x$ ; let the total height of the column of mercury and gas above the surface of the fluid in the trough  $= h$ ; the altitude of the Barometer  $= p'$ ; then the true volume at that pressure,

$$V' = \frac{x}{p'} \cdot \{p' - (h - x)\};$$

and  $V'$  may be reduced to  $V$ , if required, by formula in (77.)

(79.) And should a similar reduction be required for gas standing over water, since  $p'$  refers to a pressure made by mercury, the preceding formula will become

$$V' = \frac{x}{p'} \cdot \left\{ p' - \frac{h - x}{13.5} \right\};$$

and this also may be reduced to the standard pressure  $p$  as the preceding.

(80.) The weight of a given volume of any gas (at Part II. Barometer 30, Thermometer 60° Fahrenheit)  $= V$  (in cubic inches)  $\times$  Specific Gravity  $\times$  .305 grains Troy, Weight. (the weight of a cubic inch of dry atmospheric air.)

(81.) The weight of a given volume of air or gas varies as its density (49.), and therefore as the pressure to which it is submitted. Hence if we have the weight of a given volume of air at a given pressure, it is easy to ascertain, by proportion, the weight of a similar volume under any other pressure.

Generally,  $\frac{W}{W'} = \frac{p}{p'}$  and  $W = W' \cdot \frac{p}{p'}$ .

*Example.* If 100 cubic inches of atmospheric air, at Barometer 28 inches, weigh 28.466 grains Troy, what will a similar volume weigh when the Barometer is at the standard altitude?

Here  $W' = 28.466$   $p = 30$   $p' = 28$ ,

$$\therefore W = \frac{30}{28} \times 28.466 = 30.5 \text{ nearly};$$

30.5 grains being the weight actually admitted at present on the experiments of Sir G. Shuckburgh.

(82.) But it is also known that all substances undergo a change of volume by Heat, and that this operates upon gases to a very considerable extent. It has been shown (HEAT, 34.) that if  $V$  be the volume of any substance at 32° Fahrenheit, and  $V'$  its new volume when heated,  $t$  the degrees that it is heated above 32°, and  $K$  the cubic dilatation of the unit of mass for each degree of Fahrenheit,

Variation of Temperature.

$$V' = V \cdot (1 + K t).$$

Hence if we know the volume of a gas  $V$  at 32° Fahrenheit, we can learn its volume  $V'$  upon its being heated any number of degrees: for it has been proved by Dalton and Gay Lussac, that  $K$ , the cubic dilatation of all gases, is  $\frac{1}{480}$  of the original volume, at 32° Fahrenheit, for each degree that they are heated.

*Example.* Let it be required to know what will 100 cubic inches of gas, at 32° Fahrenheit, become in volume when heated to 60° Fahrenheit.

Here  $V = 100$   $t = 28$  and  $K = \frac{1}{480}$ ,

$$\therefore V' = 100 \cdot \left( 1 + \frac{28}{480} \right) = \frac{50800}{480} = 105.83 \text{ cubic in.}$$

(83.) But it has also been shown (HEAT, 35.) that the volume at any other temperature may be introduced into the formula without having recourse to the volume at 32° Fahrenheit; and this is a case of more frequent occurrence than the former.

For if  $V$  be the volume at 32° Fahrenheit,  $V'$  that at temperature  $t'$ , and  $V''$  that at temperature  $t''$ , we have from the general theorem, calling  $K$  the cubic dilatation as before,

$$\frac{V'}{V''} = \frac{V (1 + K t')}{V (1 + K t'')}.$$

Hence by division we have

$$\text{generally, } V'' = V' \cdot \frac{1 + K t''}{1 + K t'},$$

$$\text{or } V'' = V' \cdot \frac{480 + t''}{480 + t'} \text{ for Fahrenheit only.}$$

*Example.* Let it be required to calculate what 100 cubic inches of gas, at temperature 50° Fahrenheit, would become, if heated to 60° Fahrenheit,

Here  $V' = 100$   $t' = 18$   $t'' = 28$  and  $K = \frac{1}{480}$ .

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Generally,  $V'' = V \cdot \frac{1 + K t''}{1 + K t'}$

$= 100 \cdot \frac{508}{498} = 102.008$  cubic inches.

Dilatation of vessel.

(84.) And since air, or gas, is frequently confined in vessels of glass or metal, which also change their absolute capacity by change of temperature, it is desirable to be able to compute the variations arising from this cause. For this we may employ the general formula given in Art. (71.)

(85.) Let it be required also to introduce into the formula last referred to an expression which may provide for simultaneously correcting the volume for any change of barometric pressure from  $p'$  to  $p''$  during the experiment.

Let  $p'$  and  $p''$  be the barometric pressures at the temperatures  $t'$  and  $t''$  respectively: then, by Art. (77.) we have

$$V'' = V' \cdot \frac{p'}{p''} \cdot \left\{ \frac{1 + t'' \theta}{1 + t' \theta} \cdot \frac{1 + t' K}{1 + t'' K} \right\},$$

which gives us the true volume due to the pressure  $p''$ .

(86.) And if further we wish to reduce this to the standard altitude of 30 inches, we have from (77.)

$$V \text{ (the volume at standard altitude)} = V'' \frac{p''}{30}.$$

Weight.

(87.) Let us next consider how the weight of a gas is made to vary by change of temperature, *i. e.*

Having the weight of a given volume of gas at a given temperature, required the weight of the same volume at some other temperature.

Generally, if  $V'$  and  $V''$  be any two volumes of gas, at temperatures  $t'$  and  $t''$  above  $32^\circ$  Fahrenheit, which volumes are both  $V$  at  $32^\circ$  Fahrenheit; the weights of any given volume of the gas being  $W'$  and  $W''$  at the temperatures  $t'$  and  $t''$  respectively.

Then, by (82.)  $V' = V (1 + k t')$ ,

and  $V'' = V (1 + k t'')$ ,

$$\therefore V' : V'' :: 1 + k t' : 1 + k t''.$$

But the weights  $\propto$  as the densities which  $\propto$  inversely as the volumes.

Hence  $W' : W'' :: 1 + k t'' : 1 + k t'$ ,

and  $W'' = W' \cdot \frac{1 + k t'}{1 + k t''}$ .

*Example.* If 100 cubic inches of gas, at temperature  $50^\circ$  Fahrenheit, weigh 50 grains, what will an equal volume of the same gas weigh at  $60^\circ$  Fahrenheit?

Generally,  $W'' = W' \frac{1 + k t'}{1 + k t''}$ ;

here  $W' = 50$   $t' = 18$   $t'' = 28$ ;

$$\therefore W'' = 50 \cdot \frac{1 + \frac{18}{480}}{1 + \frac{28}{480}} = 49.015 \text{ grains.}$$

Pressure and temperature for volume.

(88.) It is frequently required to apply both the last corrections to a quantity of gas obtained in some experiment; hence

Having a given volume of gas under a given pressure and temperature; required the new volume when both pressure and temperature are changed.

This Problem may be solved at two steps: first ascertaining the change from temperature by (83.), and then the change by pressure by (77.); but it is neater to embody both in one formula.

For this purpose call the original volume, temperature above  $32^\circ$  Fahrenheit; and pressure;  $V'$ ,  $t'$ , and  $p'$ , respectively.

And let  $t''$  and  $p''$  be the new excess of temperature above  $32^\circ$  Fahrenheit and the new pressure; while  $V''$  is the new corrected volume. Also let  $Q$  be the new volume corrected for temperature but not for pressure.

Then by (83.)  $Q = V' \cdot \frac{1 + k t''}{1 + k t'}$ , which corrects temperature only;

and by (77.)  $\frac{V''}{Q} = \frac{p'}{p''}$ ,

or  $V'' = Q \cdot \frac{p'}{p''}$ , which corrects for pressure,

$$= V' \cdot \frac{p'}{p''} \cdot \frac{1 + k t''}{1 + k t'} \text{ by substitution.}$$

*Example.* Having 100 cubic inches of gas at  $50^\circ$  Fahrenheit and Barometer 29 inches; required the volume of this at  $60^\circ$  Fahrenheit and Barometer 30 inches.

Generally (88.)  $V'' = V' \cdot \frac{p'}{p''} \cdot \frac{1 + k t''}{1 + k t'}$ .

Here  $V' = 100$   $p' = 29$   $p'' = 30$   $t' = 50 - 32 = 18$   $t'' = 28$ ;

$$\therefore V'' = 100 \cdot \frac{29}{30} \cdot \frac{508}{498} = 98.6 \text{ cubic inches.}$$

(89.) Similarly. Having the weight, pressure, and The same temperature of a given volume of gas: required the for weight. weight of an equal volume when pressure and temperature both vary.

The same notation remaining, let  $Q$  represent the new weight produced, supposing the temperature alone had varied.

Then by (87.)  $Q = W' \cdot \frac{1 + k t'}{1 + k t''}$ .

But weight  $\propto$  density  $\propto$  pressure,

$$\therefore \frac{W''}{Q} = \frac{p'}{p''}, \text{ and } W'' = Q \cdot \frac{p'}{p''},$$

and by substituting the value of  $Q$  before obtained

$$W'' = W' \cdot \frac{p'}{p''} \cdot \frac{1 + k t'}{1 + k t''}$$

*Example.* If 100 cubic inches of gas, Thermometer  $50^\circ$  Fahrenheit, Barometer 29 inches, weigh 50 grains; what will 100 cubic inches weigh, Thermometer  $60^\circ$  Fahrenheit, Barometer 30 inches?

Generally,  $W'' = W' \cdot \frac{p'}{p''} \cdot \frac{1 + k t'}{1 + k t''}$ .

Here  $W' = 50$   $p' = 29$   $p'' = 30$   $t' = 50 - 32 = 18$  and  $t'' = 28$ ;

$$\therefore W'' = 50 \cdot \frac{30}{29} \cdot \frac{498}{508} = 50.706 \text{ grains.}$$

(90.) All that has hitherto been said respecting the True for all properties of a pure and dry gas applies equally to dry gases, atmospheric air, or to a mixture of gases, provided

Chemistry. only that no moisture be present, since it is proved by the experiments of Gay Lussac that all gases undergo the same dilatations by the same increments of temperature. And that the actual *cubic dilatation* of gas, in being heated from 32° Fahrenheit to 212° Fahrenheit, is .375 of the original volume: so that (HEAT, 52.) the cubic dilatation due to one degree

$$\left. \begin{aligned} \text{of Fahrenheit} &= \frac{1}{480} = 0.002083 \\ \text{of Centigrade} &= \frac{1}{266.66} = 0.00375 \\ \text{of Reaumur} &= \frac{1}{213.33} = 0.0046875 \end{aligned} \right\} \text{of the volume at melting ice.}$$

#### Moist Gases.

Effect of moisture

(91.) The general principles which regulate the effects of moisture when present in gases have been already noticed in the *Treatise on HEAT*, (79.) *et seq.*, we would offer, therefore, in as concise a form as possible, the practical results which demand the Chemist's remembrance and attention.

Let  $V_d$  be the volume of a dry gas and  $V_m$  the volume to which the former increases upon being saturated with moisture.

Let  $p$  = the atmospheric pressure, or the tension of the dry gas.

Let  $f$  = the tension of the vapour due to the temperature and to be found from tables.

Then since the elasticity of a gas varies inversely as its volume.

Elasticity of dry gas ( $p$ ) : elasticity of moist ::  $V_m$  :  $V_d$ ,

$$\therefore \text{Elasticity of moist} = p \cdot \frac{V_d}{V_m}.$$

$$\text{But (HEAT, 91.) } p = p \cdot \frac{V_d}{V_m} + f.$$

$$\text{Hence } V_d = \frac{p-f}{p} \cdot V_m.$$

$$\text{and } V_m = \frac{p}{p-f} \cdot V_d.$$

*Example.* Having 100 cubic inches of gas saturated with moisture at Barometer 30 and Thermometer 60° Fahrenheit. Required the volume of this gas when dry.

Here  $f = .524$  by Dalton's tables  $p = 30$   $V_m = 100$ ;

$$\therefore V_d = \frac{30 - .524}{30} \cdot 100 = 98.253 \text{ cubic inches.}$$

(92.) And if  $V_v$  represent a virtual volume due to the vapour, or, in other words, the quantity by which  $V_d$  is increased by the moisture,

$$V_m = V_d + V_v = \frac{p}{f} V_v.$$

$$\text{and } V_v = \frac{f}{p} V_m.$$

$$\text{or, } = \frac{f}{p-f} \cdot V_d.$$

(93.) Supposing that we had a given volume of a moist gas at some given temperature and pressure, it is

easy to reduce this volume to that which is due to the standard temperature and pressure by (88.): but we only speak of such a change as shall not condense the moisture.

Thence having the volume of moist gas we obtain the volume of dry gas therein contained by (91.)

(94.) But suppose that we had obtained the specific gravity of a gas in a state of saturation; and that it was required to calculate the specific gravity of the same gas when dry.

Let  $p$  = the barometric pressure.

Let  $f$  = the elasticity of the vapour due to the temperature found from Tables, *HEAT, Encyclopædia Metropolitana*, Appendix, Table V. and Art. (79.) of that Treatise, and let  $S_d$ ,  $S_v$ , and  $S_m$  be the specific gravities of the dry gas, the vapour diffused throughout the volume of gas, and of the moist gas respectively.  $V_m$ ,  $V_d$ , and  $V_v$  the volumes respectively.

$$\text{Then } V_m S_m a = V_d S_d a + V_v S_v a,$$

where  $a$  = the weight of a cubic inch of the gas at the given temperature and pressure; for instance, in the case of atmospheric air at Barometer 30 Thermometer 60° Fahrenheit,  $a = .305$  Troy grains,

$$\therefore V_m S_m = \frac{p-f}{p} V_m S_d + V_v S_v;$$

and if we suppose that the specific gravity which we have taken from the Table is the one belonging to a volume of vapour equal to the entire original volume of moist gas,

$$V_v = V_m,$$

$$\text{so that } S_m = \frac{p-f}{p} \cdot S_d + S_v,$$

$$\text{or } S_d = \frac{p}{p-f} \cdot (S_m - S_v).$$

But if, on the other hand, we conceive that the volume of vapour is to be estimated on the supposition that its volume is reduced to the volume of the dry gas, then  $V_v$  becomes =  $V_d$ .

$$\text{and we have } S_m = \frac{p-f}{p} (S_d + S_v),$$

$$\text{or } S_d = \frac{p}{p-f} S_m - S_v.$$

which is the view taken by Professor Thomson, in his interesting experiments, *First Principles*, vol. i. p. 66.

(95.) Formula for obtaining  $f$  immediately may be seen in the *Treatise on HEAT*, (79.)—(82.): or its value may be found from the Table V., Appendix to the same Treatise.

(96.) In these calculations we frequently require the specific gravity of vapours, especially that of the vapour of water at different temperatures. Now, as far as we at present know, the specific gravity of vapour in contact with the fluid from which it is formed varies directly as the elastic force of that vapour. *HEAT, Encyclopædia Metropolitana*. (77.)

$$\text{Hence } S_v = \frac{f_v}{f_{212}} \times S_{212},$$

where  $S_v$  and  $S_{212}$  represent the specific gravities at  $n^\circ$  Fahrenheit and 212° Fahrenheit respectively,  $f_v$  and

Chemistry.  $S_{\text{air}}$  the elastic forces due to the temperatures; which may be found from the Table V., HEAT, *Encyclopædia Metropolitana*, Appendix: and  $S_{\text{air}}$  from Gay Lussac's experiments, = .62;

$$\therefore S_{\text{air}} = \frac{f_{\text{air}}}{30} .62.$$

(97.) Should the case occur of gas confined in vessels standing over other liquids, the same formula would serve, varying only the expressions of Art. (79.), which depends upon the specific gravity of the liquid; and of Art. (94.), which depends upon the specific gravity of the vapour of the liquid, at the temperature of any experiment.

#### Mixed and Moist Gases.

(98.) And it is obvious that calculations on mixed gases are easily made on the principles already laid down; remembering that they differ in specific gravity, but all undergo equal expansions or contractions by equal changes of temperature, or by equal variations of pressure.

#### On taking the Specific Gravity of Gases.

practical method.

(99.) Being now competent to introduce the necessary corrections, we may proceed to the practical processes for ascertaining the specific gravity of gases. For this purpose we require a good air-pump; a large flask with a stop-cock; and an air-jar graduated into cubic inches and provided also with a stop-cock.

To obtain then the weight of a known volume of any gas, the flask is to be exhausted, then most accurately weighed, then filled with the gas by screwing it to the stop-cock of the air jar containing the gas: the weight is to be then again taken, and it is evident that the increase of weight is the weight due to the number of cubic inches that have entered the flask, as shown by the air-jar.

The specific gravity of dry atmospheric air is always made unity, and the weight of one cubic inch of dry atmospheric air is .305 grains Troy at Barometer 30, Thermometer 60° Fahrenheit.

Therefore at any pressure  $p$  and any temperature Fahrenheit, let  $V$  cubic inches of a dry or moist gas weigh  $W$  grains; and let  $a$  be the weight of a cubic inch of dry atmospheric air at the pressure  $p$  and temperature  $t$ ° Fahrenheit; so that the weight of a volume  $V$  of dry common air at  $p$  and  $t$  would be  $= aV$ , then

$$S \text{ (the specific gravity of the gas dry or moist)} = \frac{W}{aV},$$

and from hence, if moist the specific gravity of the same gas when dry may be found from Art. (94.)

(100.) Professor Thomson has proposed and employed a method still more simple for taking the specific gravity of gases, with this advantage, that it is more independent of a very accurate exhaustion of the flask.

Let  $W$ ,  $W'$ , and  $W''$ , be the weights of the flask before exhaustion, after exhaustion, and when filled with the gas respectively.

Then  $W - W'$  is the weight of the atmospheric air removed from the flask: and  $W'' - W'$  is the weight of the gas admitted; and since the volumes are in both cases the same, the specific gravities are as the weights directly.

$$\text{Hence } S \text{ (the specific gravity of the gas)} = \frac{W'' - W'}{W - W'} \quad \text{Part II.}$$

which gives the specific gravity of the gas dry or moist, as it may happen to be, and is so far independent of the atmospheric pressure and temperature.

#### Specific Gravity of Vapours.

(101.) By far the best method for ascertaining the specific gravity of vapours is that contrived by M. Gay Lussac, and well described in Biot's *Physique*, vol. i. p. 291. The principle employed is that of ascertaining the relative volumes of a body in the liquid state, and of the same body when converted into vapour at a known temperature. We fear that it would occupy too much space, or the process is well worthy of insertion in this place.

#### Power of Conducting Heat.

(102.) A heated body, if placed under similar circumstances, will cool with different velocities in different gases. We are of opinion that this can scarcely be said to depend solely upon a difference in the conducting power of these bodies; in some degree this may be the case, but probably the effect produced depends chiefly upon the motion of the gaseous molecules by which currents are produced, and thus the heat is successively carried off rather than truly conducted. These views are favoured by the circumstance that the powers of different gases in favouring the escape of caloric from a heated body, seem to be in some inverse ratio of their density. It was found by Dulong and Petit that the nature of the surface of the heated body did not affect the results; but it has been shown by Count Rumford's experiments, that moisture in all gases materially aids their power to abstract caloric from the heated body.

Variable power of conducting heat.

This subject has engaged the attention of Mr. Dalton and Sir H. Davy; the latter suffered the bulb of a Thermometer, which had been heated to 160° Fahrenheit, to cool in 21 cubic inches of each gas, at temperature 52° Fahrenheit.

The thermometer cooled down to 106° Fahrenheit in the different gases, in the following times:

	m.	sec.
Atmospheric air . . . . .	2	0
Hydrogen . . . . .	0	45
Olefiant gas . . . . .	1	15
Coal gas . . . . .	0	55
Azote . . . . .	1	30
Oxygen . . . . .	1	47
Nitrous oxide . . . . .	2	30
Carbonic acid . . . . .	2	45
Chlorine . . . . .	3	6

(103.) The different gases possess different powers in the propagation of sound; but this subject forms rather a part of the Science of Acoustics. *Vid.* Kirby, Merriek, and Leslie's experiments, in *Nich. Jour.* xxvii. and xxxiii.; *Phil Mag.* xly.; *Trans. Camb. Phil. Soc.* vol. i.

Power of producing sound.

(104.) It has been already stated (66.) and (72.) that certain Solids and Liquids absorb Gases. On this subject we cannot do better than offer the following excellent statement by Dr. Henry.

"All solid bodies, that possess a certain degree of Solidity, are capable of absorbing gases.

Chemistry.

"This was first observed in charcoal. It has been found also by Saussure, jun. to belong to a stone called meer-schaum, to adhesive slate, asbestos, rock cork, and other minerals; and to raw silk and wool. The following general principles are deducible from the experiments of Saussure. (h.)

1. "It is necessary to deprive the solid of the air which it naturally contains. When of a nature not to be injured by heat, this is most effectually done by igniting the solid, and quenching it under mercury, where it is to be kept, till admitted to a given volume of the gas to be absorbed. Solids that are decomposable by heat, may be deprived, though less effectually, of air, by placing them under a receiver, which must then be exhausted by the air-pump.

2. "The same solid absorbs different quantities of different gases. Charcoal, for instance, condenses 90 times its bulk of ammoniacal gas, and not twice its bulk of hydrogen.

3. "Solids, chemically the same, absorb different quantities of the same gas, according to their state of mechanical aggregation. Thus the dense charcoal of box-wood absorbed  $7\frac{1}{2}$  volumes of air, while a light charcoal, prepared from cork, did not absorb a sensible quantity.

4. "Different solids absorb different quantities of the same gas; the quantity of carbonic acid absorbed by charcoal being about seven times greater than that absorbed by meer-schaum.

5. "When the solid exerts no chemical action on the gas, the absorption is terminated in 24 or 36 hours.

6. "The effect of moistening the solid is to retard the absorption, and to diminish its amount; and when a gas has actually been absorbed, it is again driven out unchanged, partly by water of the ordinary temperature, and entirely by exposure to a boiling heat.

7. "During the absorption of a gas by a solid, the temperature of the latter rises several degrees, and bears a proportion to the absorbability of the gas, and the rapidity with which it is condensed.

8. "Solids condense a greater number of volumes of the more absorbable gases, under a rare than under a dense atmosphere; but if the absorption be reckoned by weight, it is most considerable under the latter state.

9. "When a solid, saturated with any one gas, is introduced into an atmosphere of any other gas, a portion of the first is expelled, and a part of the second takes its place.

"Gases are absorbed by liquids."

On this subject the following general principles may be laid down.

1. "The same liquid absorbs different quantities of different gases. Thus water takes up its own bulk of carbonic acid, and not one-fiftieth of its bulk of hydrogen gas.

2. "Different liquids absorb different quantities of the same gas. Alcohol, for instance, absorbs almost twice as much carbonic acid as is taken up by an equal volume of water.

3. "The absorption is promoted by first freeing the liquid from air, either by long-continued boiling in a vessel with a narrow neck, or by the air-pump. It requires also brisk and long-continued agitation, especially with the less absorbable gases.

4. "It does not appear that the gases are absorbed by all liquids in the same order. For example, of

four gases, naphtha absorbs most olefiant gas; oil of lavender most nitrous oxide; olive oil most carbonic acid; and solution of muriate of potash most carbonic oxide.

5. "The viscosity of liquids, though it does not much influence the amount absorbed, occasions a longer time to be spent in effecting the absorption. On the other hand, the amount of any gas which is absorbed by water, is diminished by first dissolving in the water any saline substance.

6. "In general the lightest liquids possess the greatest power of absorbing gases; whereas, when there is no evident Chemical action, the heaviest gases are absorbed most copiously, and rapidly, by the same liquid.

7. "The temperature of a liquid is raised by the absorption of a gas, in proportion to the amount and the rapidity of the absorption.

8. "In all liquids the quantity of gases absorbed are directly as the pressure. For example, a liquid which absorbs its own bulk of gas under the pressure of the atmosphere, will still absorb its own bulk of the same gas under double, triple, &c. pressure; but its own bulk of gas, twice compressed, is equal to double its bulk of gas ordinarily compressed, and so on. The proofs of this law I have given at length in the *Philosophical Transactions* for 1803.

9. "When water, or, probably, any other liquid, is agitated with a limited quantity of any mixture of two gases, it does not absorb one gas to the exclusion of the other, but absorbs a portion of both. In this case, the density of each gas, in the water or liquid, has a constant relation to that without, for the same gas. Thus in carbonic acid gas, the density is the same within and without the water; in olefiant gas and phosphuretted hydrogen, the density within is 1.27th of that without; in azote and hydrogen, it is about 1.50th, according to Dalton, though he originally stated it to be 1.64th, under the impression that the distances of the particles within were always some multiple of those without. This concise enunciation of the general law, deduced by Mr. Dalton from his experimental inquiries, will be better understood by the illustrations contained in a Paper published in the *Annals of Philosophy*, vol. vii. p. 216, where the reader will find a formula for ascertaining the quantities of mixed gases absorbed by water.

"The principle on which gases are absorbed and retained by liquids is still a subject of controversy. By Berthollet, Thomson, Saussure, and the generality of Chemists, it is ascribed, in all cases, to the exertion of a Chemical affinity between the gas and the liquid; but it is contended by Mr. Dalton and myself, that the effect in most cases is chiefly, if not wholly, mechanical. The discussion would lead me into details of too great a length; and I refer, therefore, for a statement of the argument, to two Papers which I have published in the eighth and ninth volume of *Nicholson's Journal*; to Mr. Dalton's *New System of Chemical Philosophy*; and to his Essay in the seventh volume of Dr. Thomaon's *Annals*, which contains a reply to the objections advanced against the mechanical theory by Saussure, in the sixth volume of the same work. This reply seems to have unaccountably escaped the notice of several writers, who continue to urge the objections of Saussure, after they have been fully and satisfactorily answered by Mr. Dalton." (i.)

Part II.

Chemistry.

(105.) It is obvious that no Chemical classification can arise out of the state of aggregation in which bodies exist; this state being entirely dependent upon Pressure and Temperature. In the usual condition of things at the surface of this Earth we are at present acquainted with four simple Gases, and about seventeen compound ones. Most of the liquid substances which bear the name of proximate elements, are combinations of those elements with water, but with some, such as the oils, the presence of water is incompatible. There are about forty-six ultimate elements in the solid state, and a much more considerable number of proximate ones formed by the combinations of these with each other or with the Gases. The simple elementary Substances amount at present to fifty-three, as enumerated in Art. (4.)

#### General Chemical Properties.

(106.) We now advance towards those properties which are more strictly Chemical—the primary object of this Treatise.

Upon these properties numerous classifications have been founded, and although in part abandoned at the present time in favour of other terms more rigidly Chemical, yet we so frequently use the words Airs, Earths, Metals, Alkalis, Acids, &c., that it will be proper briefly to enumerate the leading characteristics of these classes of substances.

Air

Gas.

The word Air is sometimes employed to designate all the permanently elastic fluids, and in this sense it is synonymous with the word Gas; but it is more commonly restricted to the atmospheric air, a mixture principally of two Gases, in which we live and breathe. The Physical properties of the Gases have been already adverted to, and their Chemical ones will form a part of our future researches, as upon these their distinctive characteristics depend.

Earths.

The term Earths is still applied to one class of substances, though rather loosely, for it has been found that in all general Chemical properties the Earths and the Metallic oxides are identical; in fact, the Earths are all oxides, and nearly all of them have Metallic Bases. As an illustration of the characteristics of this class of bodies we give the following definition from a good but early Chemical author, who says, "Earths are insipid; soluble, but in very small proportion, in pure water or oil; not inflammable, not ductile; not fusible *per se*." By insipid we are to understand not acid, nor alkaline. And the powers of the Voltaic pile and the Gas blowpipe have shown that they are fusible *per se*. When, in the language of modern Chemistry the word Earth occurs, we must understand by it some one of the following oxides:—Silica, Zirconia, Yttria, Glycina, Thorina, Alumina, Magnesia, Lime, Strontia, or Baryta. Where the Alkaline Earths are spoken of, it is to the three last enumerated that the term applies.

Metals.

The Metals are distinctively recognised to be such by their Physical properties, and not by their Chemical ones. Of these the two that are considered essential, are that they conduct Electricity, and that they possess some degree of lustre. They are all capable of combining with Oxygen, though with very different degrees of facility. The Metals at present known amount to forty.

Alkalis.

Substances of another sort are called the Alkalis, a well marked though not a numerous class of Bodies.

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Part II.

The term Alkali is derived from the Arabic name of the plant (*Salsola Kali*), from which one of these substances has long been extracted. The general properties of the Alkalis, especially as developed in the stronger ones, are as follows:—They change blue vegetable colours to green; and if such colours have been changed to purple or to a more vivid red by acids, they destroy that sort of action, and when used in sufficient quantity turn them absolutely to green. The same powers they possess even when saturated with Carbonic Acid—a property which the Alkaline Earths are without. Their taste is acrid, possibly in great degree arising from their power of dissolving all animal matter with an energy proportionate to their state of concentration. They readily combine with oils or fatty matters, so as to form soaps. Their carbonates are soluble in water, but the carbonates of the Alkaline Earths are not so. Three of the Alkalis consist of Metallic Bases, united with Oxygen: viz. Potassa, Soda, and Lithia. One, viz. Ammonia, consists of two Gases, Hydrogen and Nitrogen; and the vegetable Alkalis, which are rather numerous, consist of various combinations of Oxygen, Hydrogen, and Carbon.

The term Acid is in familiar use, and is generally understood by all: its Chemical sense accords with, or is in fact adopted from ordinary language. Acids are substances having a sour taste; they are frequently highly corrosive of animal and vegetable bodies, and they change purple vegetable colours to a brighter red. Their most distinctive Chemical property is that they unite with other substances called bases, such as the Alkalis, the Earths, and Metallic oxides, and form a new class of bodies called Salts, in which the antagonist properties of both Acid and base undergo great modifications, or are absolutely annihilated.

We are in the habit of saying that one Acid is stronger than another, but the measure of the strength of the Acids respectively is not without some uncertainty. Various propositions have been made as to the scale to be adopted for this purpose, but none of these are quite free from objections. That which is most employed was proposed by Berthollet, and is taken from the relative quantities of different Acids required to saturate a given quantity of some base, but the plan is not free from objections.

The theory of Acidification, that is the effective cause producing acid properties, has engaged the attention of several Chemists; but as at this time there cannot be said to be any prevailing belief on the subject, we content ourselves with pointing out, by a reference, where the student may find any information that he may require on this subject. (k.)

(107.) The Etymology of the word Oxygen perpetuates the memory of a belief that once existed of that substance forming the element essential to the development of acid properties. This was, however, an error, as it will be seen from the following lists that the presence of Oxygen is not necessary to the formation of an Acid; and also that Hydrogen, which is in many cases the antagonist of Oxygen, is capable of becoming the acidifying principle: while in some Acids neither the one nor the other exists.

Class 1. Acids with Oxygen, and a nonmetallic radical:

1. Chloric. 2. Oxidic. 3. Bromic. 4. Carbonic. 5. Boracic. 6. Phosphorous. 7. Phosphoric. 8. Hyposulphurous. 9. Sulphurous. 10. Hyposulphuric.

Chemistry. 11. Sulphuric. 12. Selenic. 13. Nitrous. 14. Nitric.  
15. Cyanic?

*Class 2. Acids with Oxygen and a metallic radical.*

1. Arsenious. 2. Arsenic. 3. Molybdous. 4. Molybdic. 5. Chromic. 6. Tungstic. 7. Columbic. 8. Antimonious. 9. Antimonic. 10. Titanic.

*Class 3. Acids without Oxygen, but with Hydrogen.*

1. Hydro-chloric. 2. Hydro-fluoric. 3. Hydriodic. 4. Hydro-bromic. 5. Hydro-sulphuric. 6. Hydro-selenic, with one or two others of more doubtful constitution.

*Class 4. Acids without Oxygen or Hydrogen.*

1. Boro-fluoric. 2. Silico-fluoric. 3. Chloriodic.

*Class 5. Organic Acids of animal and vegetable origin.* Of these there are about sixty, which we shall have occasion to enumerate hereafter.

From divisions like these no Chemical classification can well arise; though it is convenient that they be remembered, for the sake of obtaining general views of groups of substances having numerous properties in common.

(108.) There are also of another sort, two well-marked classes into which all substances are frequently divided. These are Inorganic and Organic. By the former we understand all such substances, whether simple or compound, as seem not to be capable of forming the chief constituents of bodies endowed with the functions of animal or vegetable life; although in such bodies they frequently exist as ultimate elements. In this division are comprehended the Metals, Earths, fixed Alkalis, the stronger Acids, and what were formerly called the simple non-metallic elements.

On the other hand, that which is called the Chemistry of Organic bodies, induces an examination of the various substances which form the existent elements, or the educts and products of animal and vegetable Organization. This branch of our Science chiefly refers to proximate elements, of which the number is very considerable. The properties of these bodies are well and distinctively marked; though in numerous cases the ultimate elements into which they may be resolved are precisely the same. Thus the Vegetable Acids and Alkalis may all be resolved into Oxygen, Hydrogen, and Carbon; and it is the various proportions in which these elements exist in the different substances which form the sole distinction discoverable upon their ultimate analysis.

(109.) We now proceed to the nomenclature of Chemical Compounds, and to the laws which regulate them, viz. the doctrines of *Affinity*, *Definite Proportion*, and the *Theory of Atoms*. After a careful examination of the systematic Treatises of our own and other Countries, and even after having prepared the greater part of what we deemed it advisable to insert upon the subject, we have not hesitated to reject it, in favour of the Essay of a contemporary writer. In the main, we consider Dr. Turner's analysis of this part of our subject as the most clear that can be presented in the present state of our knowledge. We, therefore, shall make a considerable abstract from his *Elements of Chemistry*, taking only the liberty of making some slight alterations or additions which appear to us, or which have been pointed out by his reviewers, to be necessary. In some degree we shall also have to bring forward and discuss Professor Thomson's additions to our nomenclature, as developed and employed in his valuable Work on the *First or Fundamental Principles of Chemistry*.

(110.) "Chemistry is indebted for its nomenclature to the labours of four celebrated Chemists, Lavoisier, Berthollet, Guyton Morveau, and Fourcroy. The principles which guided them in its construction are exceedingly simple and ingenious. The known elementary substances, and the more familiar compound ones, were allowed to retain the appellations which general usage had assigned to them. The newly discovered elements were named from some striking property. Thus, as it was supposed that acidity was always owing to the presence of the vital air discovered by Priestley and Scheele, they gave it the name of Oxygen, derived from two Greek words signifying generator of Acid; and they called inflammable air Hydrogen, from the circumstance of its entering into the composition of water."

"Compounds in which Oxygen forms a part were called Acids or Oxides, according as they do or do not possess acidity. An oxide of iron or copper signifies a combination of those metals with Oxygen, which has no acid properties. The name of an Acid was derived from the substance acidified by the Oxygen, to which was added the termination *ic*. Thus Sulphuric and Carbonic Acids signify acid compounds of Sulphur and Carbon with Oxygen Gas. If sulphur or any other body should form two Acids, that which contains the least quantity of Oxygen is made to terminate in *ous*, as Sulphurous Acid. The termination *urel* was intended to denote combinations of the simple non-metallic substances either with one another, with a metal, or with a metallic oxide." This plan is still adhered to in France in the words Chloruret, Ioduret, &c. but in our own Country the analogy of the word oxide has been followed in the case of the five electro-negative bodies; thus we say chloride, iodide, fluoride, &c. "Sulphuret and carburet of iron, for example, signify compounds of sulphur or carbon with iron. The different oxides or sulphurets of the same substance were distinguished from one another by some epithet, which was commonly derived from the colour of the compound, such as the black and red oxides of iron, the black and red sulphurets of mercury. Though this practice is still continued occasionally, it is now more customary to distinguish degrees of oxidation by the use of derivatives from the Greek. Protoxide signifies the first degree of oxidation, Deutoxide the second, Trutoxide the third, and Peroxide the highest." The last term is rather objectionable, as being a departure from the Greek system of derivation, and as it is liable to be changed from new discoveries in the extent of oxidation. "The sulphurets, carburets, &c. of the same substance are designated in a similar way. The combination of Acids with Alkalis, Earths, or Metallic oxides, were termed Salts, the names of which were so contrived as to indicate the substances contained in them. If the acidified substance contains a maximum of oxygen, the name of the Salt terminates in *ate*; if a minimum, the termination in *ite* is employed. Thus the sulphate, phosphate, and arseniate of potash, are Salts of sulphuric, phosphoric, and arsenic Acids; while the terms sulphite, phosphite, and arsenite of potash denote combinations of that Alkali with the sulphurous, phosphorous, and arsenious Acids." This method, however, is found insufficient for its purpose, as it only provides for two degrees of oxygenation; hence the intermediate terms of *hypo* and *hyper* have been subsequently introduced.

"The advantage of a nomenclature which disposes

Part II.

Organic  
and Inorganic  
bodies.

Nomen-  
clature.

Chemistry, the different parts of a Science in so systematic an order, and gives such powerful assistance to the memory, is incalculable. The principle has been acknowledged in all Countries where Chemical Science is cultivated, and the minutest details of it have been adopted in Britain. It must be admitted, indeed, that some parts of it are defective. The erroneous idea of oxygen being the general acidifying principle has exercised an injurious influence over the whole structure. It would have been convenient also to have had a different name for hydrogen; but it is now too late to attempt a change, for the confusion attending such an innovation would more than counterbalance its advantages. The original nomenclature has therefore been preserved, and such additions made to it as the progress of the Science rendered necessary. The most essential improvement has been suggested by the discovery of the laws of Chemical combination. The different Salts formed of the same constituents were formerly divided into *neutral*, *super*, and *subsals*. They were called neutral, if the Acid and Alkali are in the proportion for neutralizing one another; supersalts, if the Acid prevails; and subsalts, if the Alkali is in excess. The name is now regulated by the atomic constitution of the Salt. If it be a compound of one atom of the Acid to one atom of the Alkali, the generic name of the Salt is employed without any other addition; but if two or more atoms of the Acid be

attached to one of the base, or two or more atoms of the base to one of the Acid, a numeral is prefixed so as to indicate its composition. The two Salts of sulphuric Acid and potash are called sulphate and bisulphate; the first containing one atom of the Acid to one atom of the Alkali; and the latter two of the former to one of the latter. The three Salts of oxalic Acid and potash are termed the *oxalate*, *binoxalate*, and *quadr-oxalate* of potash; because one atom of the Alkali is united with one atom of Acid in the first, with two in the second, and with four in the third Salt. As the numerals which denote the atoms of the Acid in a super-salt are derived from the Latin language, Dr. Thomson proposes to employ the Greek numerals, *dis*, *tris*, *tetrakis*, &c. to signify the atoms of Alkali in a subsalt.

"This method is in the true spirit of the original framers of our nomenclature. Chemists have already begun to apply the same principle to other compounds besides Salts; and there can be no doubt that it will be applied universally whenever our knowledge shall be in a state to admit of it." (L.)

(111.) The following paradigma will, perhaps, render the system of nomenclature more intelligible to the Chemical student.

For the sake of brevity, S. M. is put for sulphate of mercury.

Suboxide of M.	Tetarto-tri S. M. = Tetarto-di S. M. = Tetarto-				S. C. = Tetarto-bi S. M. = Tetarto-ter S. M. = &c.			
	Trito-tetraki S. M. = Trito-tri S. M. = Trito-di S. M. = Trito-				S. M. = Trito-bi S. M. = Trito-ter S. M. = Trito-quater S. M.			
	Deuto-tetraki S. M. = Deuto-tri S. M. = Deuto-di S. M. = Deuto-				S. M. = Deuto-bi S. M. = Deuto-ter S. M. = Deuto-quater S. M.			
	Proto-tetraki S. M. = Proto-tri S. M. = Proto-di S. M. = Proto-				S. M. = Proto-bi S. M. = Proto-ter S. M. = Proto-quater S. M.			
	Sub-tetraki S. M. = Sub-tri S. M. = Sub-di S. M. = Sub-				S. M. = Sub-bi S. M. = Sub-ter S. M. = Sub-quater S. M.			

The preceding scheme is only the rigid development of a plan proposed by Professor Thomson, in

the Introduction to his *First Principles*, published in 1825.



Chemistry.

The degrees of oxidation are marked by prefixes derived from the Greek, which, to be consistent, run Proto-, Deuto-, Trito-, Tetarto-, &c. First, Second, Third, Fourth, &c. The only deviation from this plan occurs in the word Sub, which should have been drawn *Græco Fonte*, but being already in use, any alteration might prove inconvenient.

Upon each degree of oxidation a series of saline combinations may be produced; and it is necessary that words should be found to express atoms of Acid or of base so many times taken. Where the atom of base remains unity, and the atom of acid is once, twice, thrice, four times, &c. taken into combination, an ascending series of Latin numerals is employed. These obviously must be *Bis, Ter, Quater*, &c. And where, on the contrary, the atom of acid remains unity, and the atoms of base multiply, a series of numerals derived from the Greek are employed upon Dr. Thomson's plan. These, of course, must be from the words *δύς, τρίς, τετράκις*, &c. as in the paradigma.

The first part, therefore, of the name of a Salt so compounded informs us in what state of oxidation the metal exists; the second part gives us the proportion between the number of atoms of Acid and of base. If this second part be of Latin derivation, we know that our compound is a *Supersalt*; if of Greek derivation, we learn that it is a *Subsalt*.

For example, *Deuto-ter-sulphate of mercury* represents a Salt having for its base the oxide composed of 2 atoms of oxygen + 1 atom of mercury; and containing 3 atoms of Acid + 1 atom of base. But by *Deuto-tri-sulphate* of mercury we should understand the same base and the same Acid united in the proportion of 1 atom of Acid + 3 atoms of base.

In compounds of 1 atom of Acid + 1 atom of base we frequently leave out the prefix Prot-, in common usage, without inconvenience; but in those cases where numerous combinations exist, it is necessary always to make use of it; otherwise cases like this might occur, viz. a confusion between *Trito-sulphate* of mercury and *Tri-sulphate* of mercury; which only become sufficiently distinct by adhering to the canon of nomenclature that gives *Trito-sulphate* of mercury and *Proto-tri-sulphate* of mercury.

The definite proportions of all combinations between simple substances are expressed by Prot-, Deut-, Trit-, &c. as in the case of the oxides. Thus we say Proto-chloride, Deut-iodide, Trito-sulphuret, &c.

Some regard must be had to euphony, and the ordinary usages of compound words in constructing such names; thus we say *Proto-bin-acetate*, and not *Proto-bi-acetate*; *Deuto-trit-osalate*, and not *Deuto-tri-osalate*.

(112.) There are, however, several metallic oxides which the above system does not enable us clearly to express. Such are those which we at present describe in terms of half atoms, saying that there are  $1\frac{1}{2}$  atoms of oxygen + 1 atom of base. It is probable that future researches will dispel this apparent anomaly, but for the present we are under the necessity of speaking of such combinations, and it would be convenient if our nomenclature could truly represent them to the mind. At present the oxide of lead containing 1 atom of oxygen + 1 atom of base is called the *Protoxide*; that containing 1.5 atom of oxygen + 1 atom of base is called the *Deutoxide*; and that containing 2 atoms of oxygen + 1 atom of base is called the *Tritoxide*. But

upon the common principles of our nomenclature, we should understand by these three words, three different oxides, containing 1, 2, and 3 atoms of oxygen respectively. It is with great diffidence, and with a full sense of the evils arising from any change made upon established names, that we venture to propose a plan for obviating this inconvenience. To obtain our end, we must borrow a custom from the German language. Ask a German what o'clock it is, and he will answer you *halb sieben*, for half-past six; and as we must keep to the Greek language for expressing the degrees of oxidation, we might use the prefix *hemi*, (*ἡμιος*, a half). Thus we should have in the case of Lead

1 Oxygen + 1 Metal = Protoxide of Lead.

$1\frac{1}{2}$  ditto + 1 ditto = Hemi-deutoxide of Lead.

2 ditto + 1 ditto = Deutoxide of Lead.

In the case of Manganese

1 Oxygen + 2 Metal = Sub-oxide.

1 ditto + 1 ditto = Protoxide.

$1\frac{1}{2}$  ditto + 1 ditto = Hemideutoxide.

2 ditto + 1 ditto = Deutoxide.

3 ditto + 1 ditto = Tritoxide.

In this manner we could express any known combination, so that the name should fully express the relative atomic proportions of its constituents. We would also adopt the practice of many Chemists in banishing for ever the prefix *Per*, which has been used to express the highest degree of oxidation, partly because it is a Latin word, and therefore should not occur in the Greek ascending series: and partly, because we are never certain that we have arrived at the extreme degree of oxidation; and are, therefore, liable to have many of our names of Salts overturned by the discovery of a new degree of oxidation beyond the one with which we were previously acquainted.

At first sight this system of nomenclature may appear to present a formidable array of unharmonious words, but it is to be remembered that only a small proportion of the compounds so described are at present known to exist; and the advantages are not inconsiderable in a system which provides for the discovery of new substances, without requiring any change in names that may previously exist; and which always serves as a scheme of *memoria technica* for the atomic constitutions of the bodies named. We must admit that the plan now proposed may be liable to this objection, that in the strict meaning of the words, Protoxide, Deutoxide, &c., the first, second, &c., oxides are expressed; so that if what we call a Hemideutoxide exists, the Deutoxide is not the second but the third oxide. To us it seems that the choice lies between various methods, which all have their imperfections; but that the advantage of that system which, together with the name of the oxide or Salt, gives us its atomic constitution, outweighs all other considerations. It is also a serious affair to change terms which usage has established, but the plan proposed can scarcely be said to do so.

#### Affinity.

(113.) "All Chemical phenomena are owing to Affinity. Affinity or Chemical attraction. It is the basis on which the Science of Chemistry is founded. It is the ruling power with reference to which all the operations of the

*Chemistry.* Chemist are conducted, and hence it forms the first and leading object of his study.

"Affinity is exerted between the minutest particles of different kinds of Matter, causing them to combine so as to form new bodies, endowed with new properties. It acts only at insensible distances; in other words, apparent contact, or the closest proximity, is necessary to its action. Every thing which prevents such contiguity is an obstacle to combination, and any force which increases the distance between particles already combined, tends to separate them permanently from each other. In the first case they do not come within the sphere of their mutual attraction; in the second they are removed out of it. It follows, therefore, that though Affinity is regarded as a specific power, distinct from the other forces which act on matter, its action may be promoted, modified, or counteracted, by several circumstances; and, consequently, in studying the phenomena produced by Affinity, it is necessary to begin by inquiring into the conditions that influence its operation.

"The most simple instance of the exercise of Chemical attraction is afforded by the mixture of two substances with one another. Water and sulphuric acid, or water and alcohol, combine readily. On the contrary, water shows little disposition to unite with sulphuric ether, and still less with oil; for, however intimately their particles may be mixed together, they are no sooner left at rest, than the ether separates almost entirely from the water, and a total separation takes place between that fluid and the oil. Sugar dissolves very sparingly in alcohol, but to any extent in water; while camphor is dissolved in very small quantity by water, but abundantly by alcohol. It appears from these examples, that Chemical attraction is exerted between different bodies with different degrees of force. There is sometimes no proof of its existence at all; between some substances it acts very feebly, and between others with great energy.

"Simple combination of two principles is a common occurrence. The solution of Salts in water, the combustion of phosphorus in oxygen gas, and the neutralization of a pure Alkali by an Acid, are instances of the kind. The phenomena are, however, often more complex. It frequently happens that the formation of a new compound is attended by the destruction of an existing one. The only condition necessary for this effect is the presence of some third body, which has a greater Affinity for one of the elements of a compound, than they have for one another. Thus oil has an affinity for the volatile Alkali ammonia, and will unite with it, forming a soapy substance called a liniment. But the ammonia has a still greater attraction for sulphuric Acid; and hence, if the Acid be added to the liniment, the Alkali will quit the oil, and unite by preference with the Acid. If a solution of camphor in alcohol be poured into water, the camphor will be set free, because the alcohol combines with the water. Sulphuric Acid, in like manner, separates baryta from Muriatic Acid. Combination and decomposition occur in each of these cases; combination of the Sulphuric Acid with the ammonia, of the water with the alcohol, and of the baryta with the sulphuric Acid; decomposition of the compounds formed of the oil and ammonia, of the alcohol and camphor, and of the Muriatic Acid and baryta. These are examples of what Bergmann calls single elective Affinity; elective, because a substance manifests, as it were, a choice for one of two others, uniting with it by preference, and to

the exclusion of the other. Many of the decompositions that occur in Chemistry, are instances of single elective Affinity.

"The order in which these decompositions take place has been expressed in Tables; of which the following, drawn up by Geoffroy, is an example:

*Sulphuric Acid.*

Baryta.  
Strontia.  
Potash.  
Soda.  
Lime.  
Ammonia.  
Magnesia.

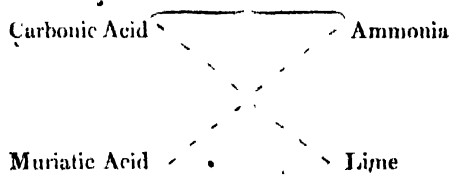
"This Table signifies, first, that Sulphuric Acid has an Affinity for the substances placed below the horizontal line, and can, therefore, unite separately with each of them; and, secondly, that the base of the Salts so formed will be separated from the Acid by adding any of the Alkalis or Earths which stand above it in the column. Thus ammonia will separate magnesia, lime ammonia, and potash lime; but none of them can withdraw baryta from Sulphuric Acid, nor can ammonia or magnesia decompose the sulphate of lime, though strontia or baryta will do it. Bergmann conceived that these decompositions were solely determined by Chemical attraction, and that, consequently, the order of decomposition represented the comparative forces of Affinity: and this view, from the simple and natural explanation it afforded of the phenomenon, was for a time very generally adopted. But Bergmann was in error. It does not necessarily follow, because lime can separate ammonia from Sulphuric Acid, that the lime has a greater attraction for the Acid than the volatile Alkali. Other causes are in operation which modify the action of Affinity to such a degree, that it is impossible to discover how much of the effect is owing to that power. It is conceivable that the ammonia may in reality have a stronger attraction for Sulphuric Acid than lime, and yet the lime, from the great influence of disturbing causes, might succeed in decomposing sulphate of ammonia.

"The justice of the foregoing remark will be made obvious by the following example: when a stream of hydrogen Gas is passed over the oxide of iron heated to redness, it deprives the iron of its oxygen entirely combining with it so as to form water. On the contrary, when watery vapour is brought into contact with red hot metallic iron, the oxygen of the water quits the hydrogen, and combines with the iron. It follows from the result of the first experiment, according to Bergmann, that hydrogen has a stronger attraction for oxygen than iron has; and from the second, that iron has a greater Affinity for oxygen than hydrogen has. But these inferences are incompatible with each other. The Affinity of hydrogen for oxygen must either be equal to that of iron, or greater or less. If the first is the case, then the result of both experiments was determined by modifying circumstances; since neither of these substances ought on this supposition to take oxygen from the other. If the second, then the decomposition in one of the experiments must have been determined by extraneous causes in direct opposition to the tendency of Affinity.

"To Berthollet is due the honour of pointing out the fallacy of Bergmann's opinion. He was the first to show that the relative forces of Chemical attraction

Chemistry. cannot always be determined by observing the order in which substances separate each other when in combination, and that the Tables of Geoffroy are merely tables of decomposition, not of Affinity. He likewise traced all the various circumstances that modify the action of Affinity, and gave a consistent explanation of the mode in which they operate. Berthollet went even a step further. He denied the existence of elective Affinity as an invariable force, capable of effecting the perfect separation of one body from another; he maintained that all the instances of complete decomposition, attributed to elective Affinity, are in reality determined by one or more of the collateral circumstances that influence its operation. But here this acute Philosopher has surely gone too far. Bergmann is admitted to have erred in supposing that the result of Chemical action is in every case owing to elective Affinity; but Berthollet certainly ran into the opposite extreme, in declaring that the effects formerly ascribed to that power, are never produced by it. That Chemical attraction is exerted between bodies with different degrees of energy is indisputable. Water has a much greater Affinity for Muriatic Acid and ammoniacal Gases than for Carbonic Acid and sulphuretted hydrogen, and for these than for oxygen and hydrogen. The attraction of lead for oxygen is greater than that of silver for the same substance. The disposition of gold and silver to combine with mercury, is greater than the attraction of platinum and iron for that fluid. As these differences cannot be accounted for by the operation of any modifying causes, we must admit a difference in the force of Affinity in producing combination. It is equally clear that in some instances the separation of bodies from one another can only be explained on the same principle. No one, I conceive, will contend that the decomposition of Hydriodic Acid by chlorine, or of sulphuretted hydrogen by iodine, is determined by the concurrence of any modifying circumstances.

"Affinity is the cause of still more complicated changes than these which have been just considered. In a case of single elective Affinity, three substances only are present, and two Affinities are in play. But it frequently happens that two compounds are mixed together, and four different Affinities brought into action. The changes that may or do occur under these circumstances are most conveniently studied by aid of a diagram, a method that was, I believe, first employed by Dr. Black, and has since been generally practised. Thus in mixing together a solution of the carbonate of ammonia and muriate of lime, their mutual action may be represented in the following manner:



"Each of the Acids has an attraction for both the bases, and hence it is possible either that the two Salts should continue as they are, or that an interchange of principles should ensue, giving rise to two new compounds, the carbonate of lime, and muriate of ammonia. According to the views of Bergmann, the result is solely dependent on the comparative strength of Affinities. If the Affinity of the Carbonic Acid for the

ammonia, and of the Muriatic Acid for the lime, exceed that of the Carbonic Acid for lime, added to that of the Muriatic Acid for ammonia, then will the two Salts experience no change whatever; but if the latter Affinities preponderate, then, as does actually happen in the present example, both the original Salts will be decomposed, and two new ones generated. Two decompositions and two combinations take place, being an instance of what is called double elective Affinity. Mr. Kirwan applied the terms quiescent and divellent, to denote the tendency of the opposing Affinities, the action of the former being to prevent a change, that of the latter to produce it.

"The doctrine of double elective Affinity was assailed by Berthollet on the same ground, and with the same success as in the case of single elective attraction. He succeeded in proving that the effect cannot always be ascribed to the sole influence of Affinity. For, to take the example already adduced, if the carbonate of ammonia decompose the muriate of lime by the mere force of a superior attraction, it is manifest that the carbonate of lime ought never to decompose the muriate of ammonia. But if these two Salts are mixed in a dry state, and exposed to heat, double decomposition does take place, carbonate of ammonia and muriate of lime being formed; and, therefore, if the change in the first example was produced by Chemical attraction alone, that in the second must have occurred in direct opposition to that power. It does not follow, however, because the result is sometimes determined by modifying conditions, that it must always be so. I apprehend that the decomposition of the solid cyanuret of mercury by sulphuretted hydrogen Gas, which takes place even at a low temperature, cannot be ascribed to any other cause than a preponderance of the divellent over the quiescent Affinities."

#### *On the Changes that accompany Chemical Action.*

"The leading circumstance that characterises Chemical action is the loss of properties, experienced by the combining substances, and the acquisition of new ones by the product of their combination. The change of property is sometimes inconsiderable. In a solution of sugar or salt in water, and in mixtures of water with alcohol or sulphuric Acid, the compound retains so much of the character of its constituents, that there is no difficulty in recognising their presence. But more generally the properties of one or both of the combining bodies disappear entirely. No ingenuity could guess *a priori* that water is a compound body, much less that it is composed of two Gases, oxygen and hydrogen, neither of which, when uncombined, has ever been compressed into a liquid. Hydrogen is one of the most inflammable substances in nature, and yet water cannot be set on fire: oxygen, on the contrary, enables bodies to burn with great brilliancy, and yet water extinguishes combustion. The Alkalis and Earths were regarded as simple till Sir H. Davy proved them to be compounds, and certainly they evince no sign whatever of containing oxygen Gas and a metal. Numerous examples of a similar kind are afforded by the action of Acids and Alkalis on one another. Sulphuric Acid and potash, for example, are highly caustic. The former is intensely sour, reddens the blue colour of vegetables, and has a strong affinity for Alkaline substances; the latter has a pungent taste, converts the blue colour of vegetables to green, and combines readily with Acids. On adding

**Chemistry.** These principles cautiously to one another a compound results, called a neutral Salt, which does not in any way affect the colouring matter of plants, and in which the other distinguishing features of the Acid and Alkali can no longer be perceived. They appear to have destroyed the properties of each other, and are hence said to neutralize one another.

"The other phenomena that accompany Chemical action are changes of Density, Temperature, Form, and Colour.

**Density.**

"1. It is observed that two bodies rarely occupy the same space after combination which they did separately. In general their bulk is diminished, so that the specific gravity of the new body is greater than the mean of its components. Thus a mixture of 100 measures of water, and an equal quantity of Sulphuric Acid, does not occupy the space of 200 measures, but considerably less. A similar contraction frequently attends the combination of Solids. Gases often experience a remarkable condensation when they unite. The elements of olefiant Gas, for example, would expand to four times the bulk of that compound, if they were suddenly to become free, and assume the Gaseous form. But the rule is not without exception. The reverse happens in some metallic compounds, and there are examples of combination between Gases without any change of bulk.

**Temperature.**

"2. A change of temperature generally accompanies Chemical action. Caloric is evolved either when there is a diminution in the bulk of the combining substances, without a change of form, or when a Gas is condensed into a liquid, or when a Liquid becomes solid. The heat caused by mixing Sulphuric Acid with water is an instance of the former; and the common process of slaking lime, during which water loses its liquid form, in combining with that Earth, is an example of the second. The rise of temperature in these cases is obviously referable to a diminution in the capacity of the new compound for caloric; but an intense degree of heat sometimes accompanies Chemical action under circumstances in which an explanation founded on a change of specific caloric is quite inadmissible. At present it is enough to have stated the fact; the theory belongs to a different branch of our Science. The production of cold seldom or never takes place during combination, except when the specific caloric is suddenly increased by the conversion of a Solid into a Liquid, or a Liquid into a Gas. All the frigorific mixtures act in this way.

"3. The changes of form that attend Chemical action are exceedingly various. The combination of Gases may give rise to a Liquid or a Solid; Solids sometimes become Liquids, or Liquids solid. Several familiar Chemical phenomena, such as explosions, effervescence, and precipitations, are owing to these changes. The sudden evolution of a large quantity of Gaseous matter occasions an explosion, as when gunpowder detonates. The slower disengagement of a Gas causes effervescence, as occurs when marble is put into Muriatic Acid. A precipitate is owing to the formation of a new body, which happens to be insoluble in the Liquid in which its elements were dissolved.

**Colour.**

"4. The colour of a compound is frequently quite different from that of the substances which form it. There does not appear to be any uniform relation between the colour of a body and that of its elements, so that it is not possible to anticipate the colour of any particular compound, by knowing the principles which

enter into its composition. Iodine, whose vapour is of a violet hue, forms a beautiful red compound with mercury, and a yellow one with lead. The brown oxide of copper generally gives rise to green and blue coloured Salts; while the Salts of the oxide of lead, which is itself yellow, are for the most part colourless. The colour of precipitates is a very important study, as it often enables the Chemist to distinguish bodies from one another when in solution."

Part II

*On the Changes of Circumstances that modify and influence the Operation of Affinity.*

"Of the conditions which are capable of promoting or counteracting the tendency to Chemical attraction, the following are the most important; Cohesion, Elasticity, Quantity of Matter, and Gravity. To these may be added the agency of the imponderables.

"The first and obvious effect of cohesion is to oppose Affinity, by impeding or preventing that mutual penetration and close proximity of the particles of different bodies, which is essential to the successful exercise of their attraction. For this reason bodies seldom act Chemically in their solid state; their molecules do not come within the sphere of attraction, and, therefore, combination cannot take place, although their affinity may in fact be considerable. Liquidity, on the contrary, favours Chemical action, it permits the closest possible approximation, while the cohesive power is comparatively so trifling as to oppose no appreciable barrier to Affinity.

"Cohesion may be diminished in two ways; either by mechanical division, or by the application of heat. The former is useful by increasing the extent of surface; but it is not of itself in general sufficient, because the particles, however minute, still retain that degree of cohesion which constitutes solidity. Caloric acts with greater effect, and never fails in promoting combination whenever the cohesive power is a barrier to it. Its intensity should always be so regulated as to produce liquefaction. It is often enough to liquefy one of the substances, as is proved by the facility with which water dissolves many Salts and other solid bodies. But it is easy to perceive that the cohesive power is still in operation; for a Solid is commonly dissolved in greater quantity when its cohesion is diminished by caloric. The reduction of both substances to the liquid state is the best method for insuring Chemical action. The slight degree of Cohesion possessed by Liquids, does not appear to cause much if "any impediment to combination"

The force of Cohesion frequently performs an important part in modifying the Physical results which Chemical Affinity would of itself produce. The forms of such products seem to depend upon the resultant of two forces not necessarily, but very frequently, opposed to each other. The one Cohesion tending to exhibit the molecules of a substance in the solid form; the other Affinity between the same molecules and a Liquid, tending to produce a compound Fluid. In some cases the former force predominates, as when Muriatic Acid, Sulphuric Acid, and baryta are mixed together, producing solid sulphate of baryta separated from the Liquid. But in other cases the resultant is determined in favour of the latter force; as when Muriatic Acid, Carbonic Acid, and lime are mixed together, producing a Fluid containing some of all the three ingredients, though Carbonic Acid and lime form a Solid. The same views we

**Chemistry.** conceive are applicable to the case of four or more ingredients. It may be just to state that these opinions are not those of Dr. Turner, to whose Work we are on these points so much indebted, and to which we shall shortly return.

**Crystallization.** Crystallization appears to be only a modification of the ordinary cohesion of Solids; it probably depends on molecular polarity. A Fluid may contain a certain quantity of a Solid in solution; but let a portion of the Liquid be evaporated, so that the quantity of the Solid remains, while the quantity of Fluid is diminished. At a certain period in this process the Affinity of the Liquid for the Solid, is in equilibrium with the force of cohesion between the molecules of the Solid; but let the evaporation be continued, the latter force will preponderate, and then the particles of the Solid will cohere. In some cases the resulting Solid will present a crystalline form; but in others it will be only a powder. This difference in result arises from the nature of the attraction with which its molecules are endued; but as far as Affinity is concerned, the cohesive force opposed to it differs not in kind, though it may possibly differ in intensity. With the measure of such difference we are at present unacquainted. Generally speaking, crystalline bodies are more soluble than those that are not so, but this rule is not invariable, and in many cases the increase of solubility depends greatly upon water of crystallization.

**Elasticity.** "From the obstacle which cohesion puts in the way of Affinity, the Gaseous state, in which the cohesive power is wholly wanting, might be expected to be peculiarly favourable to Chemical action. The reverse, however, is the fact. Bodies evince little disposition to unite when presented to each other in the elastic form. Combination does indeed sometimes take place, in consequence of a very energetic attraction; but examples of an opposite kind are much more common. Oxygen and hydrogen, and chlorine and hydrogen, though their mutual Affinity is very powerful, may be preserved together for any length of time without combining. The cause of this is obviously the distance between the particles preventing that close approximation which is so necessary to the successful exercise of Affinity. Hence many Gases cannot be made to unite directly; which nevertheless combine readily while in their nascent state; that is while in the act of assuming the Gaseous form by the decomposition of some of their solid or fluid combinations.

"Elasticity operates likewise as a decomposing agent. If two Gases whose reciprocal attraction is feeble, suffer considerable condensation when they unite, the compound will be decomposed by very slight causes. The chloride of nitrogen, which is an oil-like Liquid, composed of the two Gases chlorine and nitrogen, answers this description completely, and it is remarkable for being the most explosive substance hitherto discovered. A slight elevation of temperature, by increasing the natural elasticity of the Gases, or the contact of substances which have an Affinity for either of them, produces an immediate explosion.

"Many familiar phenomena of decomposition are owing to Elasticity. All compounds that contain a volatile and a fixed principle are liable to be decomposed by a high temperature." This statement has been objected to (*m*), and with reason, if by "liable to" we are to understand "certain to;" but, probably, the meaning is only that a tendency thence results, which in some cases may produce decomposition, but in others

does not so. In the Review by which the objection is advanced the following apposite cases are cited, viz. that hydrate of copper is decomposed by a red heat, while hydrate of potash is not so. The compound of chloride of phosphorus and ammonia, which contains three elementary Gases, and a very volatile Solid, is not only very difficult of decomposition, but is not volatilized at a red heat. Where, however, decomposition does occur we may return to Dr. Turner's explanation of the process. "The expansion occasioned by caloric removes the elements of the compound to a greater distance from one another, and thus, by diminishing the force of Chemical attraction, favours the tendency of the volatile principle to assume the form which is natural to it. Many solid substances which contain water in a state of intimate combination, part with it in a strong heat, in consequence of the volatile nature of that Liquid. The separation of oxygen from some metals by heat alone, is explicable on the same principle.

"It appears from these and some preceding remarks, that the influence of caloric over Affinity is variable; for at one time it promotes Chemical union, and opposes it at another. Its action, however, is always consistent. Whenever the cohesive power is an obstacle to combination, caloric favours Affinity, as by diminishing the cohesion of a Solid, or by converting a Solid into a Liquid. As the cause of the Gaseous state, on the contrary, it keeps particles at a distance which would otherwise unite; or by producing expansion, it tends to separate substances from one another, which are already combined. There is one effect of caloric which seems somewhat anomalous; namely, the combination of Gases on the approach of flame. The explanation given of it by Berthollet is, probably, correct,—that the sudden dilatation of the Gases in the immediate vicinity of the flame, acts as a violent compressing power to the contiguous portions, and thus brings them within the sphere of their attraction.

"The influence of quantity of Matter over Affinity is universally admitted. If one body A unites with another body B in several proportions, that compound will be most difficult of decomposition which contains the smallest quantity of B. Of the three oxides of lead, for instance, the peroxide parts most easily with its oxygen by the action of caloric; a higher temperature is required to decompose the deutoxide, and the protoxide will bear the strongest heat of our furnaces without losing a particle of its oxygen.

"The influence of quantity over Chemical attraction may be further illustrated by the phenomena of solution. When equal weights of a soluble Salt are added in succession to a given quantity of water, which is capable of dissolving almost the whole of the Salt employed, the first portion of the Salt will disappear more readily than the second, the second than the third, the third than the fourth, and so on. The affinity of the water for the saline substance diminishes with each addition, till at last it is weakened to such a degree as to be unable to overcome the cohesion of the Salt. The process then ceases, and a saturated solution is obtained.

"Quantity of Matter is employed advantageously in many Chemical operations. If, for instance, a Chemist is desirous of separating an Acid from a metallic oxide by means of the superior Affinity of potash for the former, he frequently uses rather more of the Alkali than is sufficient for neutralizing the Acid. He takes the precaution of employing an excess of Alkali, in order the

Quantity of  
Matter

Chemistry. more effectually to bring every particle of the substance to be decomposed in contact with the decomposing agent.

But Berthollet has attributed a much greater influence to quantity of Matter. It was the basis of his doctrine, developed in the *Statique Chimique*, that bodies cannot be wholly separated from each other by the affinity of a third substance for one element of a compound; and to explain why a superior Chemical attraction does not produce the effect which might be expected from it, he contended that quantity of Matter compensated for a weaker affinity. From the cooperation of several disturbing causes, Berthollet perceived that the force of Affinity cannot be estimated with certainty by observing the order of decomposition; and he, therefore, had recourse to another method. He set out by supposing that the Affinity of different Acids for the same alkali is in the inverse ratio of the ponderable quantity of each, which is necessary for neutralizing equal quantities of the alkali. Thus, if two parts of one Acid A, and one part of another Acid B, are required to neutralize equal quantities of the alkali C, it was inferred that the Affinity of B for C was twice as great as that of A. He conceived further, that as two parts of A produce the same neutralizing effect as one part of B, the attraction exerted by any alkali towards the two parts of A ought to be precisely the same as for the one part of B; and he hence concluded that there is no reason why the alkali should prefer the small quantity of one to the large quantity of the other. On this he founded the principle that quantity of Matter compensates for force of attraction.

Berthollet has here obviously confounded two things, namely, force of attraction and neutralizing power, which are really different, and ought to be held distinct. The relative weights of muriatic and sulphuric Acids required to neutralize an equal quantity of any alkali, or, in other words, their capacities of saturation, are as 37 to 40, a ratio which remains constant with respect to all other alkalis. The Affinity of these Acids will, according to Berthollet's rule, be expressed by the same numbers. But in taking this estimate we have to make three assumptions, all of which are disputable. There is no proof, in the first place, that muriatic Acid has a greater Affinity for an alkali, such as potash, than sulphuric Acid. Such an inference would be directly opposed to the general opinion founded on the order of decomposition: and though that order is by no means a satisfactory test of the strength of Affinity, it would be improper to adopt an opposite conclusion without having good reasons for doing so. Secondly, were it established that muriatic Acid has the greater Affinity, it does not follow that the attraction of these Acids for potash is in the ratio of 37 to 40. And, thirdly, supposing this point settled, it is very improbable that the ratio of their Affinity for one alkali will apply to all others; analogy would lead us to anticipate the reverse. Independently of these objections, M. Dulong has found that the principle of Berthollet is not in accord with the results of experiment.

Though this mode of determining the relative forces of Affinity cannot be admitted, it is possible that quantity of Matter may, some how or other, compensate for a weaker Affinity, and Berthollet attempts to prove it by experiment. On boiling the sulphate of baryta with an equal weight of pure potash, the alkali is found to have deprived the baryta of a small portion of its Acid:

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and on treating oxalate of lime with nitric Acid, some nitrate of lime is generated. As these partial decompositions are contrary to the supposed order of elective Affinity, it was conceived that they were produced by quantity of Matter acting in opposition to force of attraction. But they by no means justify such a conclusion. In the decomposition of sulphate of baryta by potash, no care was taken to exclude the atmospheric air during the operation; the alkali must consequently have absorbed carbonic Acid; and it is an established fact, that carbonate of potash decomposes partially the sulphate of baryta. A similar omission appears to have been made in the other experiments, where decomposition was attempted by pure potash or soda. In many cases the result may fairly be attributed to other causes. A circumstance that influences the result of such experiments, and which Berthollet left out of view entirely, is the affinity of Salts for one another. On the whole therefore, we may infer that Berthollet has given no satisfactory case in which quantity of Matter is proved to compensate for a weaker Affinity. Saline substances indeed seem ill adapted to such researches. For it is impossible in many, if not in most cases, to decide upon the relative strength of attraction of two Acids for an alkali, or of two alkalis for an Acid, which, nevertheless, is an important element in the inquiry; and even did we possess such knowledge, the influence of modifying circumstances is such, that it is difficult to appreciate the share they may have in producing a given effect.

The influence of Gravity is perceptible when it is wished to make two substances unite, the densities of which are different. In a case of simple solution, a larger quantity of saline matter is found at the bottom than at the top of the Liquid, unless the solution shall have been well mixed subsequently to its formation. In making an alloy of two metals which differ from one another in density, a larger quantity of the heavier metal will be found at the lower than in the upper part of the compound, unless great care be taken to counteract the tendency of Gravity by agitation. This force obviously acts, like the cohesive power, in preventing a sufficient degree of approximation.

(114.) The agency of Caloric, Light, Electricity Impounded, and Magnetism upon Chemical Affinity has been already generally adverted to. See (5.)--(40.)

#### On the Measure of Affinity.

As foregoing observations prove that the order of decomposition is not always a satisfactory measure of Affinity, it becomes a question whether there are any means of determining the comparative forces of Chemical attraction. When no disturbing causes operate, the phenomena of decomposition afford a sure criterion; but when the conclusions obtained in this way are doubtful, assistance may be frequently derived from other sources. The surest indications are procured by observing the tendency of different substances to unite with the same principle, under the same circumstances, and subsequently by marking the comparative facility of decomposition when the compounds so formed are exposed to the same decomposing agent. Thus on exposing gold, lead, and iron to air and moisture, the iron rusts with great rapidity, the lead is only tarnished, and the silver retains its lustre. It is hence inferred that iron has the greatest Affinity for oxygen, lead next,



Chemistry. and silver least. This conclusion is supported by concurring observations of a like nature, and confirmed by the circumstances under which the oxides of those metals part with their oxygen. The oxide of silver is reduced by heat alone; and the oxide of lead is decomposed by charcoal at a lower temperature than the oxide of iron.

"It is inferred from the action of caloric on the carbonates of potash, baryta, lime, and the oxide of lead, that potash has a stronger attraction for carbonic Acid than baryta, baryta than lime, and lime than the oxide of lead. The Affinity of different substances for water may be determined in a similar manner.

"Of all Chemical substances our knowledge of the relative degrees of attraction of the Acids and alkalis for each other is the most uncertain. Their action on one another is affected by so many circumstances, that it is in most cases impossible, with certainty, to refer any effect to its real cause. The only methods that have been hitherto devised for remedying this defect are those of Berthollet and Kirwan. Both of them are founded on the capacities of saturation; and the objections which have been urged to the rule suggested by the first Philosopher, apply equally to that proposed by the second. But this uncertainty is of no great consequence in practice. We know perfectly the order of decomposition, whatever may be the actual forces by which it is effected.

*On the Proportions in which bodies unite, and on the Laws of Combination.*

(115.) "The study of the proportions in which bodies unite naturally resolves itself into two parts. The first includes compounds whose elements appear to unite in a great many proportions; the second comprehends those, the elements of which combine in a few proportions only.

I. "The compounds contained in the first division are of two kinds. In one, combination takes place unlimitedly in all proportions; in the other, it occurs in every proportion within a certain limit. The union of water with alcohol and the liquid Acids, such as the sulphuric, muriatic, and nitric Acids, are instances of the first mode of Combination; the solutions of Salts in water are examples of the second. One drop of sulphuric Acid may be diffused through a gallon of water, or a drop of water through a gallon of the Acid; or they may be mixed together in any intermediate proportions, and in each case they appear to unite perfectly with one another. A hundred grains of water, on the contrary, will dissolve any quantity of sea salt which does not exceed forty grains. Its dissolving power then ceases, because the cohesion of the Solid becomes comparatively too powerful for the force of affinity. The limit to Combination is, in such instances, owing to the cohesive power; and but for the obstacle which it occasions, the salt would, most probably, unite with the water in every proportion.

"All the substances that unite in many proportions, give rise to compounds which have this common character, that their elements are united by a feeble affinity, and preserve when combined more or less of the properties which they possess in a separate state. In a Scientific point of view, these Combinations are of minor importance; but they are exceedingly useful as instruments of research. They enable the Chemist to present

bodies to one another, under the most favourable circumstances possible for acting with effect; the liquid form is thus communicated to them, while the affinity of the solvent or menstruum, which holds them in solution, is not sufficiently powerful to interfere with their attraction for one another.

II. "The most interesting series of compounds is produced by substances which unite in a few proportions only; and which, in combining, lose more or less completely the properties that distinguished them when separate. Of these bodies, some form but one Combination. Thus there is only one compound of zinc and oxygen, or of chlorine and hydrogen. Others combine in two proportions. For example, two compounds are formed by copper and oxygen, or by hydrogen and oxygen. Other bodies again unite in three, four, five, or even six proportions, which is the greatest number of compounds that any two substances are known to produce, excepting those which belong to the first division.

"The Combination of substances that unite in a few proportions only, is regulated by three remarkable laws. The first of these laws is, that the composition of bodies is fixed and invariable; that a compound substance, so long as it retains its characteristic properties, must always consist of the same elements united together in the same proportion. Sulphuric Acid, for example, is always composed of sulphur and oxygen, in the ratio of 16 parts (by weight) of the former to 24 of the latter: no other elements can form it, neither can its own elements in any other proportion form it. Water, in like manner, is formed of 1 part of hydrogen and 8 of oxygen; and were these two elements to unite in any other proportion, some new compound different from water would be the product. The same observation applies to all other substances, however complicated, and at whatever period they were produced. Thus sulphate of baryta, whether formed Ages ago by the hand of nature, or quite recently by the operations of the Chemist, is always composed of 40 parts of sulphuric Acid and 78 parts of baryta. This law, in fact, is universal and permanent. Its importance is equally manifest. It is the essential basis of Chemistry, without which the Science itself could have no existence.

"Two views have been proposed by way of accounting for this law. The explanation now universally given of it is confined to a mere statement, that substances are disposed to combine in those proportions to which they are so strictly limited, in preference to any others; it is regarded as an ultimate fact, because the phenomena are explicable on no other known principle. A different doctrine was advanced by the celebrated Berthollet, in his *Statique Chimique*, published in 1803. Having observed the influence of cohesion and elasticity in modifying the action of affinity, as already described, he thought he could trace the operation of the same causes in producing the effect at present under consideration. Finding that the solubility of a Salt and of a Gas in water was limited in the first by cohesion, and in the second by elasticity, he conceived that the same forces would account for the unchangeable composition of certain compounds. He maintained, therefore, that within certain limits, bodies have a tendency to unite in every proportion; and that Combination is never definite and invariable, except when rendered so by the operation of modifying causes, such as cohesion, insolubility, elasticity, quantity of Matter, and the like

Chemistry. Thus, according to Berthollet, sulphate of baryta is composed of 40 parts of sulphuric Acid and 78 of baryta, not because these substances are disposed to unite in that ratio rather than in any other, but because the compound so constituted has a great cohesive power.

"These opinions, which, if true, would shake the whole Science of Chemistry to its foundation, were founded on observation and experiments, supported by all the ingenuity of that highly gifted Philosopher. They were ably and successfully combated by Proust, in several Papers published in the *Journal de Physique*, wherein he proved that the metals are disposed to combine with oxygen and with sulphur only in one or two proportions, which are definite and invariable. The controversy which ensued between these eminent Chemists on that occasion, is remarkable for the moderation with which it was conducted on both sides, and has been properly quoted by Berzelius as a model for all future controversialists. How much soever opinion may have been divided upon this important question at that period, the dispute is now at an end. The infinite variety of new facts, similar to those observed by Proust, which have since been established, has proved beyond a doubt that the leading principle of Berthollet is quite erroneous. The tendency of bodies to unite in definite proportions only, is indeed so great as to excite a suspicion that all substances combine in this way; and that the exceptions thought to be afforded by the phenomena of solution, are rather apparent than real; for it is conceivable that the apparent variety of proportion noticed in such cases may arise from the mixture of a few definite compounds with each other.

"The second law of Combination is still more remarkable than the first. It has given plausibility to an ingenious hypothesis concerning the ultimate particles of matter, called the Atomic Theory. The law itself, however, contains nothing hypothetical, being the pure expression of a fact first established by Mr. Dalton, and subsequently by many other Chemists. The nature of it will be at once understood by a simple perusal of the following table:

Water is composed of	hydrogen	1	+	oxygen	8
Deutoxide of hydrogen	ditto	1	+	ditto	16
Carbonic oxide	carbon	6	+	ditto	8
Carbonic Acid	ditto	6	+	ditto	16
Hypsulphurous Acid	sulphur	16	+	ditto	8
Sulphurous Acid	ditto	16	+	ditto	16
Sulphuric Acid	ditto	16	+	ditto	24
Nitrous oxide	nitrogen	14	+	ditto	8
Nitric oxide	ditto	14	+	ditto	16
Hyponitrous Acid	ditto	14	+	ditto	24
Nitrous Acid	ditto	14	+	ditto	32
Nitric Acid	ditto	14	+	ditto	40

"Now it will be perceived that in all these compounds, the numbers denoting the oxygen, which is attached to a given weight of the same base, bear a very simple ratio to one another. The deutoxide of hydrogen contains just twice as much oxygen as water does. The oxygen in carbonic Acid is double that of carbonic oxide. The oxygen in the compounds of nitrogen and oxygen is in the ratio of 1, 2, 3, 4, and 5. So obvious, indeed, is this law, that it is observed at once when we compare the result of a few accurate analyses together; and the only subject of surprise is, that it was not discovered before. It is by no means

confined to the compounds of combustibles with oxygen. Thus the sulphur in the two sulphurets of mercury, the chlorine in the two chlorides of mercury, is as 1 to 2. It extends also to the Salts. The bicarbonate of potassa, for example, contains twice as much carbonic Acid as the carbonate; and the oxalic Acid of the three oxalates of potassa is in the ratio of 1, 2, and 4. We must regard it, therefore, as a general law, the enunciation of which may be stated in the following terms. When two substances, A and B, unite chemically, the quantities of the two bodies must either be equal, or in the ratio of multiples or submultiples of each other. It is often called the law of multiples, or of Combination in multiple proportion.

"Every one who hears this singular law announced for the first time, will naturally inquire if it really holds good in all cases. It may be stated in reply, that the examination of numerous compound bodies leaves no room to question the universality of the law; but that it is impossible from the present condition of the Science that every instance should be in accord with it. Two causes are in operation which tend to prevent such perfect coincidence. In the first place, we are not yet acquainted with all possible combinations; and secondly, our knowledge of the composition of known substances is not always precise; circumstances which will not excite surprise when it is considered, that the Science of Chemistry itself, and especially the Art of making accurate analyses, is of very recent origin. The mode in which the first cause operates is obvious: the effect of the second may be illustrated by a few examples. A few years ago Chemists were acquainted with only two compounds of sulphur and oxygen, the sulphurous and sulphuric Acids; the former of which is composed of 16 sulphur and 16 oxygen, and the latter of 16 sulphur and 24 oxygen. The quantity of oxygen combined with the same weight of sulphur in these compounds is in the ratio of 2 to 3. But this exception to the law of multiples was only apparent, arising from our ignorance of the hypsulphurous Acid, a compound which was first noticed by Gay Lussac in the year 1813. It is composed of 16 parts of sulphur and 8 of oxygen, so that the oxygen in the three compounds is as 1, 2, and 3. Arsenic affords an example of the same kind, in which, however, the anomaly is not yet explained. We know only two combinations of arsenic and oxygen which are thus constituted:

	Arsenic.	Oxygen.
Arsenious Acid.....	38	+ 16
Arsenic Acid.....	38	+ 24

in which the oxygen is as 2 to 3. But we may confidently expect, on two grounds, that an oxide of arsenic will hereafter be discovered; first, because there is the analogous case of sulphur to justify such a supposition; and, secondly, because arsenic may be expected to form, like the other metals, a salifiable base with oxygen. The three compounds of oxygen and lead are composed of

	Lead.	Oxygen.
Protoxide. . . . .	104	+ 8
Deutoxide (hemideutoxide, E. M.)..	104	+ 12
Peroxide (deutoxide, E. M.) . . . . .	104	+ 16

and the proportion of oxygen, therefore, is as 1, 1½, and 2. But it is manifest that the discovery of an oxide formed of 104 to 4 of oxygen, would at once make these compounds harmonize with Mr. Dalton's law.



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"The third law of Combinations is as fully as remarkable as the preceding, and is intimately connected with it. Water and hyposulphurous Acid may be adduced by way of illustration. The former is composed of 8 oxygen + 1 hydrogen; the latter of 8 oxygen + 16 sulphur. Now it is singular, that the well-known substance, sulphuretted hydrogen, is constituted of 1 hydrogen + 16 sulphur; that is, the quantities of hydrogen and of sulphur, which combine with the same quantity of oxygen, combine with one another. Again, 40 parts of selenium with 8 of oxygen form the oxide of selenium, and with 1 of hydrogen, seleniuretted hydrogen: 36 parts of chlorine with 8 of oxygen constitute the oxide of chlorine, and with 1 of hydrogen form muriatic Acid Gas; 16 parts of sulphur combine with 36 of chlorine to form the chloride of sulphur.

"It is manifest from these examples, that bodies unite according to proportionable numbers; and hence has arisen the use of certain terms, as proportion, combining proportion, or equivalent, to express them. Thus the combining proportions of the substances just alluded to are

Hydrogen .....	1
Oxygen .....	8
Sulphur .....	16
Chlorine .....	36
Selenium .....	40

"When one body combines with another in more than one proportion, then the law of multiples already explained comes into action. Thus,

	Sulphur.	Oxygen.
Hyposulph. Acid is composed of	16 or 1 pr. +	8 or 1 pr.
Sulphurous Acid .....	16 or 1 pr. +	16 or 2 pr.
Sulphuric Acid .....	16 or 1 pr. +	24 or 3 pr.

"The most common kind of combination is one proportion of one body either with one or with two proportions of another. Combinations of 1 + 3, or 1 + 4, are very uncommon, unless the more simple compounds likewise exist. Ammonia, however, is a singular instance of the reverse. It is composed of nitrogen 14 parts + hydrogen 3 parts. Now, 14 is the precise quantity of nitrogen which unites with 8 of oxygen; and, therefore, 14 is considered as one proportion of nitrogen, which is consequently combined with three proportions of hydrogen. It is probable that compounds of 1 + 1 and 1 + 2 will hereafter be discovered, but they are quite unknown at present.

"But this law does not apply to elementary substances only, since compound bodies have their combining proportions, which may likewise be expressed in numbers. Thus, since water is composed of one proportion, or 8 of oxygen, and one proportion, or 1 of hydrogen, its combining proportion is 9. The proportion of sulphuric Acid is 40, because it is a compound of one proportion, or 16 of sulphur, and three proportions, or 24 of oxygen; and in like manner the combining proportion of muriatic Acid is 37, because it is a compound of one proportion, or 36 of chlorine, and one proportion, or 1 of hydrogen. The proportional number of potassium is 40, and as that quantity combines with 8 of oxygen to form potash, the combining proportion of potash is 48. Now when these compounds unite, one proportion of the one combines with one, two, three, or more proportions of the other, precisely as the simple substances do. The hydrate of potash, for example, is constituted of 48 potash and 9 of water, and its combining proportion is

consequently  $48 + 9 = 57$ . The sulphate of potash is composed of 40 sulphuric Acid + 48 potash; and the muriate of the same alkali of 37 muriatic Acid + 48 potash. The combining proportion of the former Salt is, therefore, 88, and of the latter 85.

"The composition of the Salts affords a very neat illustration of this subject, and to exemplify it still further, a list is subjoined of the proportional numbers of a few Acids and alkaline bases.

Fluoric Acid.....	10	Lithia.....	18
Phosphoric Acid..	28	Magnesia...	20
Muriatic Acid....	37	Lime.....	28
Sulphuric Acid....	40	Soda.....	32
Nitric Acid.....	54	Potash.....	48
Arsenic Acid.....	62	Strontia.....	52
		Baryta.....	78

"It will be seen at a glance, that the neutralizing power of the different alkalis is very different; for the proportion of each base expresses the precise quantity required to neutralize a proportion of each of the Acids. Thus, 18 of lithia, 32 of soda, and 78 of baryta, combine with 10 of fluoric Acid, forming the neutral fluates of lithia, soda, and baryta. The same fact is obvious with respect to the Acids; for 28 of phosphoric, 40 of sulphuric, and 62 of arsenic Acid, unite with 28 of lime, forming a neutral phosphate, sulphate, and arseniate of lime.

"These circumstances afford a ready explanation of a curious fact, first noticed by the Saxon Chemist Wenzel; that when two neutral Salts mutually decompose each other the resulting compounds are likewise neutral. The cause of this fact is now obvious. If 88 parts of neutral sulphate of potash are mixed with 132 of the nitrate of baryta, the 78 baryta unite with the 40 sulphuric Acid, and the 54 nitric Acid of the nitrate combine with the 48 potash of the sulphate, not a particle of the Acid or alkali remaining in an uncombined condition.

	Sulphate of potash	Nitrate of baryta.
Sulphuric Acid..	40	54 Nitric Acid.
Potash.....	48	78 Baryta.
	88	132

"It matters not whether more or less than 88 parts of sulphate of potash are added; if more, a smaller quantity of sulphate of potash will remain in solution; if less, nitrate of baryta will be in excess; but in either case the neutrality will not be affected.

"The utility of being acquainted with these important laws is almost too evident to require mention. Through their aid, and by remembering the proportional numbers of a few elementary substances, the composition of an extensive range of compound bodies may be calculated with facility. By knowing that 6 is the combining proportion of carbon, and 8 of oxygen, it is easy to recollect the composition of carbonic oxide and carbonic Acid; the first being 6 carbon + 8 oxygen; and the second 6 carbon + 16 oxygen. Forty is the number of potassium, and potash being its protoxide, is composed of 4 potassium + 8 oxygen. From these few data we know at once the composition of the carbonate and bicarbonate of potash. The first is 22 carbonic Acid + 48 potash; the second, 44 carbonic Acid + 48 potash. This is done with very little effort of the memory; and the assistance derived from the

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Chemistry. method will be manifest on comparing it with the common practice of setting down the composition in 100 parts.

	Carbonic oxide.	Carbonic acid.
Carbon .....	42.86 .....	27.27
Oxygen .....	57.14 .....	72.73
	Carbonate of potash.	Bicarbonate of potash.
Carbonic Acid ..	31.43 .....	47.83
Potash .....	68.57 .....	52.17

"From the same data, calculations, which would otherwise be difficult or tedious, may be made rapidly, and with ease, without reference to books, and frequently by a simple mental process. The exact quantities of substances required to produce a given effect can be determined with certainty, thus affording information which is often necessary to the success of Chemical processes, and of vast consequence both in the practice of the Chemical arts and in the operations of Pharmacy.

"The same knowledge affords a good test to the analyst by which he may judge of the accuracy of his result, and even sometimes correct an analysis which he has not the means of performing with rigid precision. Thus a powerful argument for the accuracy of an analysis is derived from the correspondence of its result with the laws of Chemical union. On the contrary, if it form an exception to them, we are authorized to regard it as doubtful, and may hence be led to detect an error, the existence of which might not otherwise have been suspected. If an oxidized body is found to contain one proportion of the combustible with 7.99 of oxygen, then the inference is unavoidable, that 8, or one proportion of oxygen, would have been the result, had the analysis been perfect. From the same cause, the discovery of a new compound, whether it has been formed by the Chemist, or exists as a mineral in the earth, is always interesting: curiosity is excited to ascertain the ratio of its constituents, and see if it be such as reasoning from the established data would lead us to conjecture.

"The composition of a substance may sometimes be determined before any analysis of it has been made. When the new alkali lithia was first discovered, Chemists did not possess a sufficient quantity of it for determining analytically how much oxygen it contained. But it is known that the neutral sulphates of the alkalis and earths are composed of one proportion of each constituent, and that the oxide contains one proportion of oxygen. If it be found, therefore, by analysis, that the neutral sulphate of lithia is composed of 40 parts of sulphuric Acid and 18 of lithia, we conclude, since 40 is one proportion of the Acid, that 18 is the equivalent for lithia, and that the oxide is formed of 8 oxygen and 10 of lithium.

"The method of determining the proportional numbers will be anticipated from what has already been said; the commencement is made by carefully analyzing a definite compound of two simple substances, which possess an extensive range of affinity. No two bodies are better adapted for this purpose than oxygen and hydrogen; and that compound is selected which contains the smallest quantity of oxygen. Water is such a substance, and it is, therefore, regarded as a compound of one proportion of oxygen + 1 proportion of hydrogen. But analysis proves that it is composed of 8 parts of the former + 1 of the latter; by which the relative weights

of their proportions are determined; that of oxygen being 8 times heavier than that of hydrogen.

"Some compounds are next examined, which contain the smallest proportion of oxygen or hydrogen, in combination with some other substance, the quantities of each being the smallest that can unite together. Carbonic oxide, with respect to carbon, and sulphuretted hydrogen, with respect to sulphur, answer this description perfectly. The former consists of 8 oxygen and 6 carbon: the latter of 1 hydrogen + 16 sulphur. The proportional number of carbon is, consequently, 6, and of sulphur 16. The proportions of all other bodies may be determined in the same manner.

"Since the proportional numbers merely express the relative quantities of different substances which combine together, it is in itself immaterial what figures are employed to express them. The only essential point is, that the relation should be strictly observed. Thus we may make the combining proportion of hydrogen 10, if we please: but then oxygen must be 80, carbon 60, and sulphur 160. We may call hydrogen 100 or 1000, or, if it were desirable to perplex the subject as much as possible, some high uneven number might be selected, provided the due relation between the different numbers is faithfully preserved. But such a practice would effectually do away with the advantage ascribed to the use of the proportional numbers, and hence it is the object of every one to employ such simple ones, that their relation may be perceived by mere inspection. As the opinion of different Chemists concerning the simplicity of numbers is somewhat at variance, we possess several series of them. Dr. Thomson, for example, makes oxygen 1, so that hydrogen is one-eighth of unity, or 0.125, carbon 0.75, and sulphur 2. Dr. Wollaston, in his scale of Chemical equivalents, fixes oxygen at 10, by which hydrogen is 1.25, carbon 7.5, and so on. According to Berzelius, oxygen is 100. And, lastly, several other Chemists, such as Dalton, Davy, Henry, and others, call hydrogen 1, and, therefore, oxygen 8. One of these series may easily be reduced to any of the others, by an obvious and simple Arithmetical process; and, excepting that of Berzelius, whose numbers are inconveniently high for practice, it is not very material to which of them the preference is given. In this Work the last method is adopted, in consequence of its containing no fractional parts.

#### *On the Atomic Theory of Mr. Dalton.*

(116.) "The brief sketch which has been given of the laws of combination, will serve to set the importance of this department of Chemical Science in its true light. It is founded, as will have been seen, on experiment alone, and the laws which have been stated are the pure expression of fact. It is not necessarily connected with any speculation, and may be kept wholly free from it.

"The reason why persons, partially acquainted with the subject, have supposed it to be of an hypothetical nature, is sufficiently obvious. It was impossible to reflect on the regularity and constancy, with which bodies obey the laws of proportion, without speculating about the cause of that regularity; and consequently, the facts themselves were no sooner noticed, than an attempt was made to explain them. Accordingly, when Mr. Dalton published his discovery of these laws, he at once incorporated the description of them with his notion of their Physical cause; and even

Chemistry. expressed the former in language suggested by the latter. Since that period, though several British Chemists of eminence, and in particular, Dr. Wollaston and Sir H. Davy, have recommended and practised an opposite course, both subjects have been but too commonly comprised under the name of Atomic Theory; and hence it has often happened, that beginners have rejected the whole as hypothetical, because they could not satisfactorily distinguish between what was founded on fact, and what was conjectural. All such perplexity would have been avoided, and this department of the Science have been far better understood, and its value more justly appreciated, had the discussion concerning the atomic constitution of bodies been always kept distinct from what it was intended to explain. When employed in this limited sense, the Atomic Theory may be discussed in a few words.

Two opposite opinions have long existed concerning the ultimate elements of Matter. It is supposed, according to one party, that every particle of Matter, however small, may be divided into smaller portions, provided our instruments and organs were adapted to the operation. Their opponents contend, on the other hand, that Matter is composed of certain atoms, which are of such a nature as not to admit of further division. These opposite opinions have, from time to time, been keenly contested, and with variable success, according to the acuteness or ingenuity of their respective champions. But it was at last perceived that no positive data existed capable of deciding the question, and its interest, therefore, gradually declined. The progress of modern Chemistry has revived the general attention to this controversy, by affording a far stronger argument in favour of the atomic constitution of bodies than was ever advanced before, and which seems almost irresistible. We have only, in fact, to assume, with Mr. Dalton, that all bodies are composed of ultimate atoms, the weight of which is different in different kinds of Matter, and we explain at once the foregoing laws of Chemical union.

According to this view, every compound is formed by a combination of the atoms of its constituents. An atom of A may combine with 1, 2, 3, or more atoms of B, an arrangement on which depends the law of multiples. If water, for example, is composed of an atom of hydrogen and an atom of oxygen, it follows that every compound of hydrogen with an additional quantity of oxygen, must contain 2, 3, or more atoms of oxygen; some multiple in a word by a whole number of the quantity of oxygen contained in water. It is equally clear, from this view of the composition of water, that the weight of an atom of oxygen is eight times heavier than an atom of hydrogen. The relative weight of the atoms of other substances may be determined in a similar manner. Thus an atom of carbon is 6 times, an atom of sulphur 16 times, and an atom of chlorine 35 times heavier than an atom of hydrogen; and this explains why they unite with one another in the proportions expressed by those numbers. What are called the proportional numbers are, in fact, nothing else but the relative weights of atoms.

No one can suppose that the laws of Chemical union are the effect of chance: there must be some cause for them in the nature of the ultimate particles of Matter. This cause, as we have just seen, is completely supplied by the supposed atomic constitution of bodies, which accounts for the phenomena in the most beautiful

and consistent manner. So perfect, indeed, is the explanation, that the existence of these laws might have been predicted by the aid of the atomic hypothesis long before they were actually discovered by analysis. But these are not the only arguments which we at present possess in favour of the existence of ultimate indivisible particles of Matter. Dr. Wollaston, in his Paper on the Finite Extent of the Atmosphere, (*Philosophical Transactions*, 1822.) has defended this side of the question on a new and independent principle, and the proof he has given of the atomic constitution of bodies appears decisive.

Some Chemists, even without expressly adopting the Atomic Theory itself, have followed Mr. Dalton in the use of the terms *atom* and *atomic weight*, in preference to *proportion*, *combining proportion*, *equivalent*, and others of a like kind. All these appellations, however, have the same signification; and, in using the word *atom*, instead of the others, it should be held in mind that it merely denotes the proportions in which bodies unite: that it is the expression of a fact which will remain the same, whether the atomic hypothesis suggested the employment of the term be true or false.

There is one circumstance which, at the first view, seems hostile to the supposed atomic constitution of Matter. In describing the law of multiples, it was mentioned that the oxygen in the three oxides of lead is the ratio of 1 : 1½ : 2: so that if we regard the protoxide as composed of one combining proportion of lead to one proportion of oxygen, the second will contain one proportion and a half, or, according to the atomic theory, one atom and a half of oxygen. Now, though the half of a combining proportion may be admitted, the existence of half an indivisible particle of Matter is inconceivable: and this circumstance would be fatal to the Atomic Theory, were there not some satisfactory mode of accounting for it. Several explanations might be brought forward. One of them, as has already been mentioned, rests on the supposition that what is called the protoxide, is, in reality, composed of one atom of lead to two atoms of oxygen; and that the real protoxide has not yet been discovered. Another mode of accounting for the anomaly is, by regarding the present deutoxide as composed of the protoxide and peroxide combined with each other. A third method is, by doubling both elements of the anomalous compound, by which the exact ratio is preserved, and the idea of the fraction of an atom is avoided. Thus the protoxide and peroxide of iron are composed, the first, of one proportion, or 28 of metal + 8 of oxygen, and the second, of 28 of metal + an atom and a half, or 12 of oxygen; or what amounts to the same thing, of 56, or two atoms of iron, to 24, or three atoms of oxygen. These observations prove, that the occurrence of half proportions is not inconsistent with the atomic constitution of bodies; they show that the difficulty is explicable, and probably will, in the progress of discovery, be entirely removed. In the mean time, however, it would be inconvenient to allow any speculative notions on the subject to interfere with actual practice; and, therefore, it is best at once to admit the occurrence of half proportions: and, if any one prefer the term *atom* to *equivalent* or *proportion*, he must submit to the somewhat jarring expression of half an atom.

Mr. Dalton supposes that the atoms of bodies are spherical, and has invented certain symbols to represent the mode in which he conceives they may combine

Chemistry, together." See his *New System of Chemical Philosophy*.

\* There are several questions relative to the nature of atoms, most of which will, perhaps, never be decided. Of this nature are the questions which relate to the actual form, size, and weight of atoms, and to the circumstances in which they mutually differ. All that we know with any certainty is, that their weights do differ, and by exact analysis the ratios between them may be determined. The numbers which indicate the combining proportions of bodies, are, in fact, the relative weights of their atoms.

"It is but justice to the memory of the late Mr. Higgins, of Dublin, to state, that he first made use of the atomic hypothesis in Chemical reasonings. In his *Comparative View of the Phlogistic and Antiphlogistic Theories*, published in 1789, he observes, (pp. 36 and 37,) that "in volatile vitriolic Acid a single ultimate particle of sulphur is intimately united only to a single particle of dephlogisticated air; and that in perfect vitriolic Acid, every single particle of sulphur is united to two of dephlogisticated air, being the quantity necessary to saturation;" and he reasons in the same way concerning the constitution of water and the compounds of nitrogen and oxygen. These remarks of Mr. Higgins do not diminish Mr. Dalton's claim of originality. They appear to have been quite unknown to him at the time he published his *New System of Chemical Philosophy*: and indeed they were made in so casual a manner, as not only to escape observation, but to prove that Mr. Higgins himself attached no particular interest to them. Mr. Dalton's real merit lies in the discovery of the laws of combination, a discovery which is solely and indisputably his; but in which he would have been anticipated by Mr. Higgins, had that Chemist perceived the importance of his own opinions. The merit of applying the atomic hypothesis to account for these laws likewise belongs to Mr. Dalton; nor is his ingenuity in the least affected by the circumstance that another person had previously explained insulated Chemical facts on the same principle.

*On the Theory of Volumes.*

• (117.) "Soon after the publication of the *New System of Chemical Philosophy* in 1808, in which Work Mr. Dalton explained his views of the atomic constitution of bodies, a Paper appeared in the second volume of the *Mémoires d'Arcueil*, by M. Gay Lussac, on the *Combination of Gaseous Substances with each other*. He there proves that Gases unite together by volume in very simple and definite proportions. In the combined researches of himself and M. Humboldt, those gentlemen found that water is composed precisely of 100 measures of oxygen and 200 measures of hydrogen; and M. Gay Lussac, being struck by this peculiarly simple proportion, was induced to examine the combinations of other Gases, with the view of ascertaining if any thing similar occurred in other instances.

" The first compounds which he examined were those of ammoniacal Gas with muriatic, carbonic, and fluoboric Acid Gases. 100 volumes of the alkali combined with precisely 100 volumes of muriatic Acid Gas, and they could be made to unite in no other ratio. With both the other Acids, on the contrary, two distinct combinations were possible. These are :

100 Fluoboric Acid Gas with	100 ammoniacal Gas.
100 Ditto	200 ditto.
100 Carbonic Acid Gas with	100 ditto.
100 Ditto	200 ditto.

## Part II

" Various other examples were quoted, both from his own experiments and from those of others, all demonstrating the same fact. Thus ammonia was found by M. A. Berthollet to consist of 100 volumes of nitrogen + 300 volumes of hydrogen. 100 volumes of sulphurous Acid and 50 volumes of oxygen produced sulphuric Acid. Carbonic Acid is composed of 50 volumes of oxygen and 100 volumes of carbonic oxide.

“From these and other instances M. Gay Lussac established the fact, that Gaseous substances unite in the simple ratio of 1 to 1, 1 to 2, 1 to 3, &c.; and this original observation has been confirmed by such a multiplicity of experiments, that it may be regarded as one of the best established laws in Chemistry. Nor does it apply to the true Gases merely, but to vapours likewise. For example, sulphuretted hydrogen, sulphurous Acid, and hydriodic Acid Gases are composed of

100 vol. hydrogen + 100 vol. vapour of sulphur.  $\frac{1}{2}$   
 100 do. oxygen. . + 100 do. do. do.  
 100 do. . . do. . . + 100 do. do. iodine.

“ There are very good grounds to suppose, also, that solid bodies which are fixed in the fire, would, when in the form of vapour, be subject to the same law. By a method which will be hereafter explained we may calculate what the Specific Gravity of carbon would be, if converted into vapour, and 0.4166 is the number so determined, atmospheric air being unity. Now if we assume that carbonic Acid is formed of 100 volumes of oxygen + 100 volumes of the vapour of carbon, condensed into the space of 100 volumes, the Specific Gravity of carbonic Acid will be  $1.1111$  (the Specific Gravity of oxygen) +  $0.4166 = 1.5277$ , which is the precise number determined by experiment. Again, it follows from our assumption, that carbonic Acid is composed by weight of

Oxygen 1.1111 . . . . 16 or 2 prop.

Carbon 0.4166 . . . . . 6 or 1 prop.

as ascertained by analysis.

“ If we assume that carbonic oxide is composed of 50 volumes of oxygen, and 100 volumes of the vapour of carbon, condensed into the space of 100 volumes, then its Specific Gravity will be  $0.5555$  (half the Specific Gravity of oxygen)  $+ 0.4166 = 0.9721$ ; and its composition will be

Oxygen 0.5555. . . . . 8 or 1 prop.

Carbon 0.4166 . . . . . 6 or 1 prop.

both of which results have been determined by other methods.

\* The compounds of carbon and hydrogen are equally illustrative of the same point. If light carburetted hydrogen is formed of 200 volumes of hydrogen + 100 volumes of the vapour of carbon, condensed into 100 volumes, its Specific Gravity should be  $0.1388$  (twice the Specific Gravity of hydrogen) +  $0.4166 = 0.5554$ ; and its composition by weight will be

Hydrogen. . . . .	0.1388. . . . .	2
Carbon. . . . .	0.4166. . . . .	6

" If olefant Gas is composed of 200 volumes of hydrogen + 200 volumes of the vapour of carbon, its

Chemistry. Specific Gravity will be  $0.1388 + 0.8332 = 0.9720$ ; and its composition by weight must be

Hydrogen....	0.1388.	.... 2
Carbon.....	0.8332.	.... 12

both of which results have been obtained by analysis.

"Another remarkable fact established by M. Gay Lussac in the same Paper is that the diminution of bulk which Gases frequently suffer in combining, is also in a very simple ratio. Thus the 4 volumes of which ammonia is constituted, (3 hydrogen + 1 nitrogen,) contract to a half or to 2 volumes when they unite. There is a contraction to two-thirds in the formation of nitrous oxide Gas. The same applies to the combination of Gases and vapours. There is contraction to a half in the formation of sulphuretted hydrogen; and to a third in that of sulphurous acid. The instances just quoted relative to the vapour of carbon confirm the same remark. There is a contraction to two-thirds in carbonic oxide, to a half in carbonic Acid, to a third in light carburetted hydrogen, and to a fourth in olefiant Gas.

"The rapid progress which Chemistry has made within the last few years, is in a great measure attributable to the ardour with which Pneumatic Chemistry has been cultivated. That very department, which at first sight appears so obscure and difficult, has afforded a greater number of leading facts than any other; and the law of Gay Lussac, by giving an additional degree of precision to such researches, as well as from its own intrinsic value, is one of the brightest discoveries that adorn the annals of the Science. The practice of estimating the quantity in weight of any Gas by measuring its volume, of itself susceptible of much accuracy, is rendered still more precise and satisfactory by the operation of this law. It will not, perhaps, be superfluous, therefore, to exemplify the method of reasoning employed in these investigations by a few examples, which will serve, moreover, as a useful specimen to the beginner of the nature of Chemical proof.

"One essential element in every inquiry of this kind, which is indeed the keystone of the whole, is a knowledge of the Specific Gravity of the Gases. But it is exceedingly difficult to determine the Specific Gravity of the Gases with perfect accuracy; for not only do slight alterations of temperature and pressure during the experiment affect the result, but the presence of a little watery vapour, atmospheric air, or other impurity, may cause a material error, especially when the Gas to be weighed is either very light or very heavy. The Specific Gravity of important Gases has accordingly been stated differently by different Chemists, and there is none in regard to which more discordant statements of this fact have been made than of hydrogen Gas. Fortunately we possess the power of correcting the results, and of estimating their accuracy, by means of other data, upon which greater reliance may be placed. According to our best data, the Specific Gravity of oxygen, hydrogen, and nitrogen Gases, air being 1, is

Oxygen.....	1.1111
Hydrogen.....	0.0694
Nitrogen.....	0.9722

"It has been proved by analysis that 200 volumes of ammoniacal Gas are composed of 300 volumes of hydrogen and 100 volumes of nitrogen, from which the Specific Gravity of that alkali may be calculated.

$$\text{Thus, } 0.9722 + (0.0694 \times 3) = 1.1804,$$

and  $1.1804 \div 4$  is the Specific Gravity ammoniacal gas should have, did its constituents suffer no contraction; but as they contract to one half, the real Specific Gravity is double what it otherwise would be, or is 0.5902. Now, if by weighing a certain quantity of ammoniacal Gas, the same number is procured for its Specific Gravity, it follows that all the elements of the calculation must have been correct.

"Nitric oxide is composed of 100 volumes of nitrogen + 100 volumes of oxygen, united without any contraction, and forming, consequently, 200 volumes of the compound. Its Specific Gravity must, therefore, be the mean of its constituents, or  $(1.1111 + 0.9722) \div 2 = 1.0416$ . The coincidence of this calculated result with that determined by weighing the Gas itself, proves that all the data are true. It is obvious, indeed, that the calculated results, as being free from the unavoidable errors of manipulation, must be the most accurate, provided the elements of the calculation may be trusted.

"Dr. Henry has proved by careful analysis that 100 volumes of light, carburetted, hydrogen Gas, a compound of carbon and hydrogen, require 200 volumes of oxygen for complete combustion; that water and carbonic Acid are the sole products; and that the latter amounts precisely to 100 volumes. From these data, the proportions of its constituents and its Specific Gravity may be determined. For 100 volumes of carbonic Acid contain 100 volumes of the vapour of carbon, which must have been present in the carburetted hydrogen, and 100 volumes of oxygen. One half of the oxygen originally employed is thus accounted for, and the remainder must have combined with hydrogen. But 100 volumes of oxygen require 200 volumes of hydrogen for combination, all of which must likewise have been contained in the carburetted hydrogen. The 100 volumes of light carburetted hydrogen submitted to analysis, are hence composed of 100 volumes of the vapour of carbon, and 200 volumes of hydrogen. Its Specific Gravity must, therefore, be 0.5554, that is  $0.4166$  (the Specific Gravity of carbon vapour)  $+ 0.1388$ , or twice the Specific Gravity of hydrogen Gas.

"Having ascertained that light carburetted hydrogen Gas is composed of two measures of hydrogen to one of the vapour of carbon, it is easy to calculate the proportion of its constituents in weight. For this purpose we need only multiply the bulk of the Gases by their respective Specific Gravities. Thus,  $200 \times 0.694 = 13.88$ , and  $100 \times 0.4166 = 41.66$ . Hence, light carburetted hydrogen is composed by weight of

Carbon.....	41.66	.... 6
Hydrogen....	13.88	.... 2

"The theory of volumes has very considerable analogy to Mr. Dalton's law of multiple proportions. The former is indeed, to a certain extent, a consequence of the latter; for if one body unites with another in several proportions, the quantities of the variable ingredient will stand in the same relation to one another, when expressed by volume, as they do by weight. But there is one remarkable difference. The weights of the two elements of a compound have no apparent dependence on one another. Thus, 6 carbon and 8 oxygen form carbonic acid; 8 oxygen and 14 nitrogen form nitrous oxide; 8 is no multiple by any whole number of 6; nor 14 of 8. But the elements of a compound are always united by volume, in the ratio of 1 to 1, 1 to 2, 1 to 3, and so on. This distinction is certainly very

Chemistry. obvious; but still there is otherwise such a similarity in the two laws, that the peculiar nature of the ultimate particles of Matter which gives rise to the one must surely be the cause of the other. It is to be hoped, therefore, that the connecting link will soon be supplied, and one fact of great interest has already been determined, which may ultimately be of use in accounting for this difference. In the Vth volume of the *Annals of Philosophy*, O. S., Dr. Prout published an Essay *On the Relation between the Specific Gravities of Bodies in their Gaseous state and the Weights of their Atoms*, in which he showed that the atomic weights, or equivalents of several substances, are multiples by a whole number of the atomic weight of hydrogen gas. Dr. Thomson took up this idea, and in his recent admirable *Treatise on the First Principles of Chemistry*, has proved that it applies generally; that the atomic weights of all the simple substances he examined are not only multiples by a whole number of the atomic weight of hydrogen, but with very few exceptions of two atoms of hydrogen.

“Dr. Prout pointed out another circumstance of much interest with respect to this question, in the Paper above alluded to. He showed that in general the Specific Gravity of a body in its gaseous state may be obtained by multiplying its atomic weight (the atom of oxygen being taken as unity) by 0.555, or half the Specific Gravity of oxygen Gas; and Dr. Thomson, in the VIIth chapter of the Work just mentioned, has discussed the subject at considerable length. The following explanation will I hope make the reason of this rule intelligible. Water is composed of one volume of oxygen to two volumes of hydrogen; and as Chemists regard it as a compound of one atom of each element, it, of course, follows that one atom of hydrogen must occupy twice the space of an atom of oxygen. It would be exceedingly convenient, did the atoms of different bodies occupy the same space when in the gaseous form; for then the atoms would be represented by volumes, and the numbers which express the relative weights of the former would be identical with the specific gravities of the gases. But it has been already stated, that an atom of oxygen occupies one half the bulk of an atom of hydrogen; and it follows, therefore, that the Specific Gravity of the former Gas must be twice as great as it would be, did it occupy the same space as the latter. Hence the rule,

as  $1 : 0.125 :: 0.5555 : 0.0694$ ,

in which 1 is the atomic weight of oxygen; 0.125 the atomic weight of hydrogen; 0.5555 half the Specific Gravity of oxygen Gas; and 0.0694 the fourth proportional, the Specific Gravity of hydrogen.

“The atoms of several other substances besides hydrogen, occupy in the gaseous state twice the space of an atom of oxygen; indeed, as far as is yet known, every simple substance, though naturally solid, is in this condition, besides the majority of compound Gases; and in all such instances it is easy to calculate the Specific Gravity of a body, by multiplying its atomic weight by 0.5555, or half the Specific Gravity of oxygen. This rule applying only when the weight of the atom is expressed according to the oxygen scale. If hydrogen be represented by unity, then the rule is to multiply 0.5555 by the atomic weight of the body, and divide by 8, the atomic weight of oxygen.

“It appears at first sight to be an easy matter to VOL. IV.

make the atoms and volumes of bodies correspond to one another; and that it might be effected by considering water as a compound of an atom of oxygen + two atoms of hydrogen. Sir H. Davy has accordingly done so in his *Elements of Chemical Philosophy*, and the atom of oxygen will, therefore, be 16, while that of hydrogen is unity. But the inconvenience arising from this practice is far greater than the evil it was intended to remedy. For on this supposition, sulphuretted hydrogen must be held as an atom of sulphur with two atoms of hydrogen, while it is composed of one volume of each of its constituents. Muriatic Acid Gas would consist of one atom of chlorine, and two atoms of hydrogen, though formed of one volume of each Gas. The same remark applies to Hydriodic Acid, Hydrocyanic Acid, and most other compound Gases containing hydrogen.

“The reason of this is that the atoms and volumes of all the simple Gases, (oxygen excepted,) and many compound ones also, according to the received system, correspond with one another. Sulphuretted hydrogen is composed of one volume or one atom of sulphur to one volume or one atom of hydrogen. Muriatic Acid is composed, in like manner, of one volume or one atom of each of its constituents. Light carburetted hydrogen is a compound of two volumes of hydrogen to one volume of the vapour of carbon, or of two atoms of hydrogen to one of carbon. All this advantage is lost by regarding water as a compound of two atoms of hydrogen to one of oxygen; and this forms a sufficient reason for not adopting the method of Sir H. Davy.”

#### On the Theory of Berzelius.

(118.) “It is well known that the celebrated Professor of Stockholm has for many years devoted himself to the study of the laws of definite proportions, and that he has been led to form a peculiar hypothesis, by way of generalizing the facts which his industry had collected. To give a detailed account of his system does not fall within the plan of this Work: to treat of the atomic theory without alluding to the labours of Berzelius, would, on the other hand, be inexcusable: a middle course will here be adopted by stating briefly the principal opinions of that eminent Chemist, offering at the same time a few comments upon them.

“Berzelius informs us in the Historical introduction to his *Treatise on the Theory of Definite Proportions*, that he commenced his researches on the subject in the year 1807; and that they originated in the study of the Works of Richter. From Richter's explanation of the fact, that when two neutral Salts decompose one another, the resulting compounds are likewise neutral, he perceived that one good analysis of a few Salts would furnish the means of calculating the composition of all others. He accordingly entered upon an inquiry, which was at first limited in its object; but as he proceeded, his views enlarged, and advancing from one step to another, he at length set about determining the laws of combination in general. In perusing his account of the investigation, we are at a loss whether most to admire the number of exact analyses which he performed, the variety of new facts he determined, his acuteness in detecting sources of error, his ingenuity in devising new analytical processes, or the persevering industry which he displayed in every part of the inquiry. But it is at the same time impossible to suppress regret, that instead of forming a complex system of his own,

Chemistry. he did not adopt the simple views of Mr. Dalton. This he might have done with very great propriety; since the fundamental laws which he discovered, are, with very little exception, either identical with those previously pointed out by the British Philosopher, or are the direct result of their operation.

"Berzelius assumes with Dalton the existence of ultimate indivisible atoms, to the combination of which with one another the laws of Chemical proportion are owing.

"The first law of Berzelius is the following: 'One atom of one element unites with 1, 2, 3, or more atoms of another element.' This is the grand law of Mr. Dalton, and requires no comment, further than that it has been amply confirmed by the labours of Berzelius. The second is, that 'two atoms of one element combine with three atoms of another.' These are the two laws which regulate the union of simple or elementary atoms.

"The combination of compound atoms with each other obeys another law, and is confined within still narrower limits. 'Two compounds which contain the same electronegative body, always combine in such a manner that the electronegative element of one is a multiple by a whole number of the same element of the other.' Thus, for instance, if two oxidized bodies unite, the oxygen of one is a multiple by a whole number of the oxygen in the other. Various examples may be given of this. The hydrate of potash is composed of

Potash 48, the oxygen of which is 8.

Water 9, the oxygen of which is 8.

"In like manner, if two Acids or two oxides combine the same will be observed.

"In the earthy minerals which contain several oxides, the same law is found to prevail with great uniformity.

"The composition of the Salts, likewise, is under its influence. Carbonate of potash, for example, is composed of

Carbonic Acid 22, the oxygen of which is 16.

Potash . . . . 48, the oxygen of which is 8.

And sulphate of potash of

"Sulphuric Acid 40, the oxygen of which is 24.

Potash . . . . 48, the oxygen of which is 8.

"Berzelius has remarked that the nitrates, phosphates, and arseniates, may prove exceptions to the law in some instances. There is also a similar relation in Salts which contain water of crystallization, between the oxygen of the base of the Salt and that of the water. For instance, crystallized sulphate of soda is composed of

Sulphuric Acid 40.

Soda . . . . 32, the oxygen of which is 8.

Water . . . . 90, the oxygen of which is 80.

"Double Salts are also influenced by the same law. In the tartarate of potash and soda, for example, the oxygen of the potash is exactly equal to the oxygen in the soda; and the oxygen in the tartaric Acid, which neutralizes the potash, is equal to that of the soda.

"But this is not all that Berzelius has remarked with respect to the constitution of the Salts. He observes, that in each series of Salts the same relation always

exists between the oxygen of the Acid and of the base. Part II. In all the neutral sulphates this ratio is as three to one; as may be seen in the sulphates of soda and potash. In the carbonates, the oxygen of the Acid is double; and in the bicarbonates quadruple the oxygen of the base.

"The existence of these remarkable laws was discovered by Berzelius at a very early period of his researches; and he mentions, that as subsequent observation during the course of several years has not afforded a single exception to them, he now regards them as universal. He accordingly places unlimited confidence in their accuracy, and is in the constant habit of calculating the composition of bodies on this principle.

"It will, of course, be interesting to inquire into the cause of these phenomena; to ascertain if there is any property peculiar to oxygen, or other negative electrics, which might give rise to them. Berzelius himself says, that 'the cause is involved in such deep obscurity, that it is impossible at the present moment to give a probable guess at it.' 1 (says Dr. Turner) have the misfortune to differ entirely from Berzelius on this question. So far from being obscure, it is perfectly intelligible, and is precisely what might have been anticipated from the present state of Chemical knowledge. Most of the Salts called neutral sulphates, are composed of one proportion or one atom of sulphuric Acid, and one atom of some peroxide. This is the case with all the alkaline and earthy sulphates, and with several of the common metals, as lead, zinc, and iron. Now an atom of sulphuric Acid is composed of

Sulphur . . 16 . . . . 1 atom.

Oxygen . . 24 . . . . 3 atoms.

And every protoxide of

Metal . . . . . 1 atom.

Oxygen . . . 8 . . . . 1 atom.

"Hence a number of laws may be deduced, which must hold in every sulphate or a protoxide.

"1. The oxygen of the Acid is a multiple of that in the base.

"2. The Acid contains three times as much oxygen as the base.

"3. The sulphur of the Acid is just double the oxygen of the base.

"4. The Acid itself is five times as much as the oxygen of the base.

"Metallic sulphurets are frequently composed of an atom of each element; and should oxidation ensue, so that the sulphur is converted into sulphuric Acid, and the metal into a protoxide, they will be in the exact proportion for forming a neutral sulphate. Berzelius has proved by analysis that this happens frequently, and he is disposed to convert it into a general law.

"Again, the carbonates are composed of one atom of carbonic Acid, and one atom of some protoxide; but an atom of carbonic Acid is composed of

Carbon . . . 6 . . . . 1 atom.

Oxygen . . 16 . . . . 2 atoms.

And every protoxide of

Metal . . . . . 1 atom.

Oxygen . . . 8 . . . . 1 atom.

"It is inferred, therefore, that in all the carbonates, the oxygen of the Acid is exactly double that of the base; and the same mode of reasoning is applicable to the various genera of Salts. These few examples



Chemistry will serve to show, that what seemed so obscure to Berzelius, is rendered quite obvious by the Daltonian method. We perceive, moreover, that no constant ratio can exist between the quantity of the oxide and that of the Acid, or oxygen of the Acid; and the reason is, because the atomic weights of the metals are different. But this view of the subject answers another useful purpose; it enables us to see whether the law of Berzelius is or is not universal. The observations made on this subject by Dr. Thomson in his *First Principles*, are so much to the point that they are here given in his own words.

"Before concluding these general observations," says Dr. Thomson, "I may say a few words on Berzelius's law, that in all Salts the atoms of oxygen in the Acid constitute a multiple by a whole number of the atoms of oxygen of the base. This law was founded upon the first set of exact analyses of neutral Salts which Berzelius made. Now, as neutral Salts in general are combinations of an atom of a protoxide with an atom of an Acid, it is obvious that the atoms of oxygen in the Acid must in all such Salts be multiples of the atom of oxygen in the base; because every whole number is a multiple of unity. Neutral Salts, therefore, are not the kind of Salts by means of which the precision of this supposed law can be put to the test."

"Even in the subsalts, composed of one atom of Acid united to two atoms of base, it is obvious enough that the law will hold whenever the Acid, combined with the base, happens to contain 2 or 4, or any even number of atoms, because all even numbers are multiples of 2. Now this is the case with the following Acids:

Phosphoric.	Nitrous.	Antimonic.	Citric.
Boracic.	Titanic.	Manganic.	Saccharic.
Arsenic.	Arsenious.	Molybdous.	Chromous.
Sulphurous.	Selenic.	Uranic.	

Consequently the law must hold good in all combinations of 1 atom of these Acids with 2 atoms of base.

"In the case of all these Acids which contain only 1 atom of oxygen, all the subsalts composed of one atom of the Acid united to 2 atoms of the base, the law will also in some sort hold; for the atoms of the oxygen in such Acids being 1, this number will always be a submultiple of 2, the number of atoms of oxygen in 2 atoms of base. This is the case with the following Acids.

Silicic.	Hyposulphurous.
Phosphorous.	Oxide of Tellurium

"It is only in the subsalts of Acids containing an odd number of atoms of oxygen, that exceptions to the law can exist. It is to them, therefore, that we must have recourse when we wish to determine whether this empirical law of Berzelius be founded in Nature or not. Now, there are 13 acids, the integrant particles of which contain an odd number of atoms of oxygen. The following Table exhibits the names of these Acids, together with the number of atoms of oxygen in each.

Sulphuric Acid . . . 3	Acetic Acid . . . . 3
Arsenic Acid . . . . 3	Succinic Acid . . . 3
Chromic Acid . . . 3	Benzoic Acid . . . 3
Molybdic Acid . . . 3	Nitric Acid . . . . 5
Tungstic Acid . . . 3	Tartaric Acid . . . 5
Oxalic Acid . . . . 3	Hyposulphuric Acid 2½
Formic Acid . . . . 3	

"Dr. Thomson informs us that the number of sub-

salts he has examined is exceedingly small, because his object was not to investigate the truth of Berzelius's law, but to determine the quantity of water of crystallization which the Salts contain. He observes that it would certainly be a most remarkable circumstance if 2 atoms of any protoxide were incapable of combining with 1 atom of any of the 13 Acids in the preceding list. Dr. T. adduces seven instances in which this does happen, three of which are completely in point, being a subsulphate of alumina, a subacetate of lead, and a subacetate of copper: and he is 'persuaded that many more will be discovered whenever the attention of Chemists is particularly turned to the subsalts.' He also mentions other kinds of Salts; in regard to which, for equally obvious reasons, the law cannot and does not hold.

"These extracts will suffice for placing the law of Berzelius in its true light; for showing that it is a direct consequence of the general operation of the laws of definite proportion: and that we must expect to find some exceptions to his law, derived from the very cause which gives rise to it. It is to be hoped that Berzelius will take the remarks of Dr. Thomson into mature consideration, by which he will probably perceive that his favourite canon is not so universal as he imagines, and be led to avoid the errors to which, from an indiscriminate employment of it, both himself and his pupils might otherwise be exposed.

"That part of the law which applies to the combined water is likewise more than doubtful. When the base contains 2 atoms of oxygen, and an uneven number of atoms of water are present, it cannot be correct. When the base contains 3 atoms of oxygen, the law would not apply whenever there chanced to be 2, 4, 8, or 10 atoms of water. When the base has only 1 atom of oxygen, then it must hold for obvious reasons. When the base has 1½ atom of oxygen, the law can only be true, when 3, 6, 9, or 12 atoms of water are in combination. With 1, 2, 4, 5, 7, 8, or 10 it must fail. The hydrate of the peroxide of iron is an exception of this kind, and similar ones are to be looked for among the crystallized Salts of the peroxide.

"An admirable attempt has been made within this few years to determine the atomic constitution of minerals, in which Berzelius has highly distinguished himself. The composition of minerals must of course be influenced by the usual laws of combination, though there are sometimes obstacles in the way of discovering it. In the compounds made artificially, Chemists possess the power of having each constituent perfectly pure; but unfortunately we cannot always command the same condition with respect to natural productions. The materials of which a mineral is composed, once formed a part of some heterogeneous fluid or semi-fluid mass, and in assuming the solid form are very likely to have enclosed within them some substance, which, Chemically considered, does not form a part of the mineral. The result of Chemical analysis, accordingly, does not always give us a view of the actual constitution of a mineral species; some substances are often detected which are foreign to it, and the Chemist must exercise his judgment in determining what is and what is not essential. Now nothing is so well calculated to direct him as a knowledge of the laws of combination: but as a great discretionary power is in his hands, it is important that his mode of investigation should be the simplest possible, and that his rules



**Chemistry.** should be founded on well-established principles, which involve nothing hypothetical. It is but very lately that due care has been bestowed in selecting sufficiently pure specimens for examination, or in performing the analyses themselves with the precision necessary for determining the Chemical constitution of minerals. It were much to be wished that our first essays in this difficult field should be confined as much as possible to such minerals as contain but few substances, and which occur in distinct transparent crystals.

"We are indebted to Berzelius for this mode of studying the composition of minerals; and certainly if skill in analytical investigation could encourage any one to make the attempt, none could undertake it with greater chance of success than the indefatigable Professor of Stockholm. Unfortunately his theoretical views are unnecessarily complex, and I much doubt, for reasons already stated, if his ruling law about multiples of oxygen deserves the confidence he bestows upon it. It will not, I am convinced, be adopted by the Chemists and Mineralogists of this Country, and I am much mistaken if, notwithstanding the great reputation of its author, it stand its ground long upon the Continent. To give a particular description of his method is foreign to our purpose, but the reader will find an able account of it in the IXth volume of the *Annals of Philosophy*, New Series, by Mr. Childrep."

(119.) The early Chemical writers were accustomed to represent all the elementary bodies by certain symbols, arbitrarily adopted, and by combinations of these they also expressed the compound substances. Should curiosity lead any one to examine this matter, we refer him to Bergman's *Work on Elective Attractions*.

Professor Berzelius has adopted a method in some respects similar, but in a greatly improved form, more suited to the present state of our Science. His fundamental symbols are formed by adopting the initial or leading letters which commence the Latin name of each substance; and by the help of figures and points, placed like indices over these symbols, he represents the atomic constitution and the degree of oxidation of each substance. It was our original intention to have given a statement of his method, but we fear that want of space may prevent us from so doing. We, therefore, for the present must refer our readers to his *Essai sur la Théorie des Proportions Chimiques*, Paris, 1819, or to Mr. Children's analysis above quoted; but should we find sufficient space, the symbols themselves shall be given in a Tabular form at the end of this Treatise.

(120.) It only now remains, before we proceed to the Chemical properties of bodies, that we should present a diagram of the method according to which each element, whether ultimate or proximate, will be considered.

- A. History of discovery, and natural state.
- B. How obtained pure; its constitution if a compound.
- C. Physical properties.
- D. Mutual action with oxygen.
- E. Mutual action with chlorine.
- F. Mutual action with fluorine.
- G. Mutual action with iodine.
- H. Mutual action with the nonmetallic electro-positive elements.
- I. Mutual action with the metallic electro-positive elements.

K. Mutual action with  $\left\{ \begin{array}{l} \text{Acids.} \\ \text{bases.} \end{array} \right.$

L. Mutual action with reagents, or distinctive properties.

M. Uses in Medicine and the Arts.

It will be obvious that, by a constant use of the above letters, simplicity of reference will be obtained, and repetitions or confusion will be avoided.

Bromine is not inserted in the above scheme, in consequence of the little that is at present known of its mutual action with other bodies.

References from (41.) to (120.) inclusive.

(a.) Faraday, *Journal of Science*, vol. iii. p. 354; and vol. vii. p. 106. (b.) *Annales de Chimie et de Physique*, vol. xvi. p. 129. (c.) Professor Thomson, *An. Phil.* vol. xvi. (d.) Gay Lussac, *An. Phil.* vol. ix. p. 16. (e.) Meinelcke, *Jour. of Science*, vol. iii. p. 415. (f.) Berzelius and DeLong, *Annales de Chimie et de Physique*, vol. xv. p. 366. (g.) Thomson on *True Atomic Weights*, p. 62. (h.) Thomson, *Annals*, vol. vi. p. 241. (i.) Henry, *Chemistry*, vol. i. p. 144. edit. 10. Lavoisier, *Elémens*. (k.) Kirwan on the Composition of Acids in his *Essay on Phlogiston*. Berthollet, *Chim. Stat.* Davy, *Elements*. Davy, *Phil. Trans.* 1810. Murray, *Edin. Phil. Trans.* vol. viii. (l.) Turner, *Elements of Chemistry*, p. 98. (m.) *An. Phil. N. S.* vol. i. p. 380. (n.) Turner, *Elements of Chemistry*, p. 148.

## CHAPTER II.

### Non-Metallic (Electronegative?) Elements.

Of the five substances that come under the above denomination, the two first, oxygen and chlorine, when quite pure, are seen only in the gaseous form at all temperatures with which we are acquainted; though under strong pressure, the latter is a liquid. Fluorine has not as yet been exhibited in an independent form, while iodine and bromine are solid, liquid, or gaseous, according to the temperature at which we examine their properties.

#### § 1.—Oxygen.

(121.) A. Oxygen Gas may be said to have been first discovered by Dr. Priestley, for on the 1st of August, 1774, he obtained it by exposing the red oxide of mercury to the heat produced by condensing the rays of solar light in the focus of a lens. Thus separated he examined its properties, and named it dephlogisticated air. In the year following, Scheele, without being aware of Priestley's discovery, obtained it by other methods; and by Lavoisier, who undertook a further examination of its properties its present name of oxygen was proposed.

Although the word *Oxygen* stands at the head of this section, we are unable to speak of oxygen in its simple state. It has never yet been seen other than in the gaseous form, when it is supposed to consist of the true base, oxygen, united with caloric. When in combination it frequently loses that form and then becomes a constituent part of solid or liquid substances. It is well to bear in mind this distinction between oxygen

Chemistry. and oxygen Gas, though the terms are frequently made use of indiscriminately; this would not, however, be the case were caloric a ponderable body, for now we may say, that oxide of zinc consists of 425 parts (by weight) of metal united with 100 parts of oxygen, or of oxygen Gas indifferently.

Oxygen exists in its gaseous state as a constituent part of the atmosphere: forming that portion which is essential to animal life and to combustion. Of almost every form and kind of matter which surrounds us it forms an ingredient. Its compounds are more numerous and diversified than those of any other substance with which we are acquainted. It produces most powerful effects in changing the properties of other simple bodies with which it combines. Thus when united to azote in one proportion it forms the genial air we breathe. Mild and salutary as are the properties of this well-known substance, yet if the proportions of the combining bodies be changed we have a powerful liquid Acid—the nitric, capable of dissolving metals and acting as an escharotic on living animal bodies. It forms a part of every earth we tread upon, and of every vegetable we see around us; and when combined with another gaseous body, hydrogen, it forms water: an important and essential form of food to all the animal and vegetable creation.

(122.) B. There are several methods by which oxygen Gas may be obtained for experimental purposes.

1. Priestley's mode already described. (a.)  
2. Scheele obtained it by the distillation of nitre. This method is still at times resorted to, but such oxygen is not very pure. A pound of nitre thus distilled in an earthen retort, at a red heat, will yield about 1200 cubic inches of Gas. (b.)

3. Scheele also obtained it from a mixture of black oxide of manganese and sulphuric Acid. In this process 4 parts of manganese may be mixed with 3 parts of sulphuric Acid, in a glass retort, and the Gas may be disengaged by the heat of an Argand's lamp.

4. Lavoisier, who had been informed by Priestley of his own researches, expelled the oxygen from red oxide of mercury by heating it in a retort; and described his process to the Royal Academy in 1755.

5. The hemideutoxide of lead, minium, or red lead of commerce, gives out pure oxygen Gas by the application of heat and is converted into the protoxide.

6. Oxygen Gas is, however, obtained most plentifully for experimental purposes, by placing any quantity of the common black oxide of manganese in an iron retort or bottle having a tube passing from it into a gasometer; this retort is placed in a fire, so as to receive a moderate red heat, when the oxygen Gas is expelled in considerable quantity.

7. But should the Gas be required of great purity it is usual to put a small quantity of the chloride of potash into a glass retort, and to apply cautiously a very moderate lamp or sand heat. The Salt first fuses and then gradually parts with a considerable quantity of very pure oxygen Gas. In this case the oxygen is disengaged from the chloric Acid, which consists of that substance and chlorine; and also from the potash, which consists of oxygen and potassium; so that dry chloride of potassium is the sole residuum found in the retort. Some care is necessary in this process, especially if a naked glass retort be employed: as the alkaline matter combines with the glass and the bottom of the retort

gives way. For this reason it is advantageous to employ a sand-bath in which the retort may be safely supported.

(123.) C. Oxygen Gas thus obtained has the following physical properties. It is without colour. It follows the general laws applying to all gaseous matter with regard to pressure and temperature. (76. and 82.) It is heavier than common air, its Specific Gravity referred to that substance being 1.1111. As 100 cubic inches of dry atmospheric air, thermometer 60° Fahrenheit, barometer 30 inches, weigh 30.5 troy grains according to Sir G. Shuckburgh, if the above Specific Gravity be correct, (and it rests upon the reasoning of the accurate Dr. Prout, confirmed by the experiments of Professor Thomson,) the same volume of oxygen, *indem positis*, will weigh 33.888 grains. It has neither smell nor taste. By a sudden and violent condensation oxygen Gas emits both light and heat. All Gases thus evolve heat upon condensation, but, according to M. Saissy, oxygen, chlorine, and common air are the only Gases that emit light under these circumstances. Of these oxygen emits the most, then chlorine, and, lastly, air. Of all Gases, oxygen has the least refractive power upon light. If the refractive power of air be 1, that of oxygen is 0.8616. Oxygen is more strongly electronegative than any other body at present known. When disengaged from all other substances in Nature by Voltaic electricity, it and its compounds invariably go to the positive pole of the pile.

When oxygen Gas is left in contact with water the quantity of Gas absorbed is scarcely perceptible; but Dr. Henry found that 100 cubic inches of water, which had been freed from all air by boiling and the air-pump, would absorb 3.55 inches of Gas. (c.) Saussure estimated that 100 cubic inches would absorb 6.53 cubic inches of Gas, (d.) but Dalton considers the former estimate much more accurate. (e.)

(124.) E. See chlorine, sect. 2. reference D.

(125.) F. See fluorine, sect. 3. ref. D.

(126.) G. See iodine, sect. 4. ref. D.

(127.) H. Oxygen unites with all the substances falling under this division: it forms compounds of very varied properties. With hydrogen it forms water, chap. iii. sect. 2. subsect. 1. With azote it forms atmospheric air and some strong Acids, chap. iii. sect. 8. subs. 1, 2, 3, 4, and 5. With sulphur it forms Acid chap. iii. sect. 6. subs. 1, 2, 3, and 4. With selenium it forms a gaseous oxide, chap. iii. sect. 7. subs. 1. With phosphorus it forms acids, chap. iii. sect. 5. subs. 1 and 2. With carbon it forms an oxide and an Acid, chap. iii. sect. 3. subs. 1 and 2. With boron it forms an Acid, ch. iii. sect. 4. subs. 1. And with silicon it forms a compound which on the whole may be considered as having acid properties, chap. iii. sect. 1. subs. 1.

(128.) I. With the metals oxygen invariably unites. In some cases in one proportion only; in others in two or more proportions. Sometimes it is held by a strong affinity, sometimes the affinity is of the feeblest possible kind. From some of these unions with the metals we obtain Alkalis; from others Earths; and from others Acids. These properties will be considered in each individual case under the metals, respectively, but as general views on this subject are of fundamental importance, we offer the following general summary by M. Thenard.

"The phenomena which oxygen Gas presents when in contact with metals are of such importance as to

Chemistry. demand our utmost attention. We ought to examine all those causes which may conduce to their production, and register the effects respectively produced by them. These causes, independent of affinity, arise principally from the hygrometric state of the oxygen Gas, and from temperature.

"Dry oxygen Gas at ordinary temperatures is absorbed by potassium; and hence we might be led to conclude that it would be also absorbed by barium, lithium, strontium, calcium, and by the metals of the first section; (i. e. those of our chap. iv. class 1.) but at the same temperature it is not absorbed by sodium, nor by any of the metals belonging to the last four sections. A certain elevation of temperature favours this action prodigiously; so that in fact by this mean it may be made to act upon all the metals, with the exception of those of the last section, (class 6.) A considerable number of them absorb oxygen when the temperature is sufficiently elevated, with the evolution of light; viz. all the metals of the second class; zinc, iron, tin, and cadmium, in the third; arsenic, antimony, tellurium, bismuth, in the fourth. Tin, antimony, and bismuth being those whose combustion is most feeble. It may seem, perhaps, extraordinary to find tellurium burning with the evolution of light, while manganese, which has much greater affinity for oxygen than it has, does not possess that property. The reason, however, is simply this, that tellurium, being both fusible and volatile, forms, *dato tempore*, a much greater quantity of oxide than manganese which is fixed and almost infusible. In fact, in order that any substance may burn with flame it must not only have a great affinity for oxygen but it must also enter into fusion readily, or be volatile, or rather, perhaps, if the oxide which it forms is readily fusible or volatile: without this, the contact between the substance burning and the substance burned, not being intimate, the combustion cannot be vivid.

"The combination of metals with oxygen Gas may almost always be effected by filling a small retort or bent tube with the Gas, over mercury, and after having introduced a certain quantity of the metal by means of a bent wire, applying the heat of a spirit-lamp and agitating the metal with the wire if necessary. It is only when the heat required is very considerable indeed, that a porcelain tube is employed. This tube containing the metal may pass through a small furnace, and may communicate by means of small glass tubes, at one extremity with an empty bladder, and at the other extremity with a bladder full of oxygen. After the furnace is lighted and the porcelain tube has become white hot, the oxygen Gas is to be passed slowly backward and forward from one bladder to the other several times. The absorption will be entire if there be sufficient metal in the tube.

"Oxygen Gas when in a humid state attacks not only the metals of the two first classes, but even many of those belonging to the third, the fourth, and even the fifth class. With regard to the former, oxidation takes place at once at the expense of the free oxygen, and also of the oxygen of the water, which is decomposed and its hydrogen liberated. With regard to the latter, the metal receives only the free oxygen; and in this case we suppose the aqueous vapour to possess a twofold action; on the one hand it may partly become liquid and hold in solution a portion of the oxygen, thus rendering this oxygen, when deprived of its elas-

ticity, more capable of combining with the metal; on the other hand, it may still further promote the combination by its own tendency to unite with the metallic oxide and form an hydrate. Be this as it may, the oxidation so produced is generally only superficial, and is always very slow in its progress: the interior parts of the metal are always protected by the exterior film, or at least a considerable time must elapse before they undergo any considerable alteration. The metals which most readily oxidize in this manner are arsenic, manganese, iron, zinc, lead, copper, &c.; those of the sixth class being unalterable.

"When the oxygen, whether it be dry or moist, is mixed with azote, its action upon the metals is the same as if the azote were not present, except that possibly that action may be less intense; for the azote acts only mechanically by diminishing the points of contact in a given space between the oxygen Gas and the metals. But since atmospheric air is composed of about four-fifths azote and one-fifth oxygen, with a little aqueous vapour and a little carbonic Acid Gas, it ought to act upon metals in the same manner as oxygen does, but with some difference of intensity. This is in fact what happens: when dry, it only attacks at ordinary temperatures the metals of the first two classes, and even is without action upon sodium: when moist, it acts not only upon all these, but also upon many metals of the third, fourth, and fifth classes. Whether dry or moist, it acts upon all by the aid of heat: those of the last class alone excepted. The result of this action is an oxide, or an hydrate. But if the process take place in the open air, the product is frequently a carbonate, especially at common temperatures: thus it is that the air, being perpetually renewed, is continually yielding small quantities of carbonic Acid to the oxide, whenever these two bodies have sufficient affinity to enter into union. Thus brass statues become gradually covered with carbonate of copper; and in leaden reservoirs, there is formed immediately above the surface of the water, not oxide of lead, but carbonate of lead."

"No carbonate can, however, be formed if the temperature be considerably elevated, except those of barium, potassium, sodium, and probably lithium; because all the carbonates decompose at that temperature except those of barytes, potash, soda, and apparently of lithia. (f.)

(129.) K. Though it does not immediately appear that any actions of the kind to which this reference applies can be described, yet we are of opinion that, with a due consideration of the mutual agencies of all bodies, it would require only ordinary ingenuity to discover a series of effects which might be ranged under this head: especially if we subscribe to Berzelius's views of the constitution of mineral bodies, and extend them to all substances in Nature.

(130.) L. Oxygen Gas is distinguished from all other bodies by the following properties. It is not inflammable; is not absorbed by a solution of caustic potassa; it is capable of restoring to full combustion a match which has been partially extinguished; it combines by the electric spark with twice its volume of hydrogen, forming water and leaving no gaseous residuum.

(131.) M. Oxygen Gas is essential to the animal economy; and although, from its powerful excitative effects, it cannot be long respired alone with impunity, yet when

Action of  
moist oxygen.

Part II.

**Chemistry.** combined with four times its volume of azote it forms the compound best adapted to our organs of respiration, viz. the air we breathe. If the oxygen be in less proportion, the air is not salubrious, and if totally absent, it will not support life for a moment. When pure oxygen Gas is respired, the evil effects of an accelerated circulation arise: the lungs become inflamed and the whole system enters upon a state of fevered excitement. Attempts have been made to exhibit oxygen in some cases of disease, but as yet these have been attended with but slender success. It is not to be understood that oxygen is the only Gas that can be breathed; but it is the only one that can be permanently breathed without derangement of some sort or other arising in the system. A singular instance of its action has been related. Three men who were employed in clearing out the vault of a *cabinet d'aisance* at Paris were suffocated by the sulphuretted hydrogen, which always exists abundantly in such places. When taken out, they were conveyed to the *Hotel Dieu*: two died on the way thither; the third arrived there alive, but without any power to move his limbs. In the haste to contrive something that should be administered to him, a bladder full of oxygen presented itself, and he was made to breathe it: the man immediately sat up, but again fell down and expired. It has been supposed that he might have been restored to life, if a small quantity of chlorine Gas, mixed with a considerable quantity of atmospheric air, had been similarly administered to him.

#### Combustion.

**Combustion.**

(132.) It might not, perhaps, be quite satisfactory were we entirely to omit all consideration of Combustion; and yet we feel that little real knowledge is to be gained by any detailed views of the numerous explanations that have been proposed on this subject. In the first place, the word itself is rather vague in its applications by different writers. Originally, Combustion was synonymous with what in common language is called the burning of any thing. The Chemist was justly called upon to explain, in the terms of Science, the conditions, the operations, and the result of that process. Subsequently, however, the explanations which were thus given led to a great extension of the applications of the dogmas advanced: and the term Combustion was made use of in cases where burning in its ordinary sense could not be said to exist. If by Combustion we mean the union of oxygen with certain bodies, attended by the production of light and heat, it is one thing; and in this case mere oxidation is excluded. But if we apply the term to any Chemical change between the elements of Matter, wherein light and heat are evolved, it is quite another thing, and there is no essential necessity for the presence of oxygen. We are of opinion that the introduction of confusion is all that is obtained by continuing to employ the word in any other than a popular sense.

Still it may be necessary, for the information of some, to state that the first Scientific explanation of Combustion was given by Stahl, who conceived that there existed in all combustible bodies a certain elementary principle which he called *phlogiston*, and that the process of Combustion depended upon the evolution of this principle. Thus a body that had been burned or oxidated, he termed *dephlogisticated*, supposing it to have lost its *phlogiston*. The heat and light which accom-

pany Combustion he explained as a consequence of the rapidity with which that principle was evolved. Thus, in truth, substituting a description of what took place, viz. the heat and the light, in place of the word Combustion; and affording no real explanation of the process.

The researches of Lavoisier overturned the theory of Stahl, and introduced another explanation of Combustion, resting far more securely upon an experimental basis. Oxygen had recently become known to Chemists, and Lavoisier showed that a dephlogisticated substance had in fact gained something, instead of having parted with something, as Stahl had asserted. He proved that those substances which were capable of Combustion, were to be considered as the more elementary of the two classes: that in the process of burning they gained weight; and that this gain of weight was due to their having taken a quantity of oxygen into combination, which they might, by certain processes, be compelled again to evolve. It only remained that he should, like Stahl, attempt to say why Combustion was attended with heat and light. Dr. Black's doctrines of latent heat and specific caloric seemed to afford a plausible explanation of this circumstance. Lavoisier, therefore, asserted, that in some cases the heat and light were due to the change of Physical state of the combining bodies: as for instance, that when phosphorus was burned in oxygen Gas, the effect was due to the great condensation experienced by the latter, in passing from the gaseous to the solid form. In other cases it was urged that the specific heat of the compound being less than that of the simples, such an evolution must take place. It has, however, been found, that these principles are insufficient to serve for a general explanation of the phenomena of Combustion. All that we now dare to assert is, that great heat, and sometimes light also, is evolved where no oxygen is present: and that intense Chemical action is all that can be supposed to be essentially present in all cases. The experiments of Dulong and Petit have proved that the specific caloric of combining and combined bodies will not afford the explanation thence anticipated by Lavoisier. (g.) And as Chemical action or affinity is all that we can recognise in the process, it has been supposed that the heat and light are due to the union of opposite electricities: a supposition that can satisfy those only who, with Davy and Berzelius, believe Chemical affinity to arise only from the opposite electrical states of the molecules of matter. Consult, also, Sir H. Davy's *Memoirs on Flame and Combustion*. (h.)

#### References in Oxygen.

(a.) Priestley on *Air*, vol. ii. p. 154. (b.) Scheele on *Air and Fire*, p. 43. (c.) *Phil. Trans.* 1803, p. 174. (d.) *An. Phil. O.S.* vol. vi. p. 340. (e.) *An. Phil. O.S.* vol. vii. p. 218. (f.) Thenard, *Syst.* vol. i. p. 273. (g.) Dulong and Petit, *An. de Ch. et Ph.* vol. x. (h.) Davy, *Phil. Trans.* 1817:

#### § 2. Chlorine.

(133.) A. It is now the prevailing opinion that Chlorine is a simple elementary body, and as such it will here be considered. The origin of this opinion must, with reference to our scheme of description, form the early History of this substance, and may be briefly stated

Chemistry. as follows. Muriatic, or marine Acid, as it was first called, was known to Chemists. Scheele first obtained Chlorine from it in 1774, and called the new substance dephlogisticated marine Acid, consonant to his own doctrines respecting phlogiston. The French Chemists changed this name to that of oxygenized muriatic Acid, and this was again altered by contracting it to oxymuriatic Acid.

Chlorine has not been discovered in an uncombined form in Nature: it exists, however, in great abundance as a constituent of muriatic Acid, which again is neutralized by various alkaline substances. Thus, as muriate of soda, it exists in the waters of the ocean: and is also found in the solid form (common salt) in large deposits in various parts of the Earth.

(134.) B. Chlorine Gas is most readily obtained by putting two parts of strong muriatic Acid mixed with one part of the common black oxide of manganese into a glass retort and applying a gentle heat. The Gas is evolved in considerable quantity, and should be received in inverted bottles over the pneumatic trough. The water with which the trough is filled should be quite warm, and the bottles when filled should all be closed with glass-stoppers, to which a little lard has been applied. Want of space will, for the most part, prevent us from tracing the progress of most of the decompositions which the processes recommended in this Treatise may present: but such considerations are of first-rate importance to the Chemist, and as an example we shall here note the rationale of the above decomposition. Black oxide of manganese consists of one atom of metal + two atoms of oxygen. Muriatic Acid of one atom of Chlorine + one atom of hydrogen. In the mutual reaction of these substances, an atom of the oxide is decomposed, so that it is reduced to a lower state of oxidation; the atom of oxygen that is set free unites with the atom of hydrogen from the muriatic Acid so as to form water: the remaining atom of Chlorine is set free; the newly formed protoxide of manganese unites with an unaltered atom of muriatic Acid, and a proto-muriate of manganese remains in the retort.

For the purposes of the manufacturer a cheaper process is employed. Three parts of common salt are well mixed with one part of the black oxide of manganese, and then put into a retort. To this a mixture of four parts of diluted sulphuric Acid (containing 3-5ths acid and 2-5ths water) is added, and a moderate heat applied as before.

(135.) C. Chlorine Gas has a yellowish green colour, from whence its name is derived. (*χλωρός*.) It is violently irritative both to the nostrils and to the fauces, and highly disagreeable and injurious if even in small quantity it reaches the lungs. By violent condensation it evolves both light and heat. Under a pressure of four atmospheres it forms a bright yellow liquid, which does not freeze at zero, Fahrenheit. Its Specific Gravity is 2.5. (Thomson.) Cold water freed from common air by boiling will absorb and retain twice its volume of this Gas. When Chlorine Gas saturated with moisture is exposed to a cold of 32° Fahrenheit, yellow crystals are formed, containing, according to Mr. Faraday, a definite proportion of one atom of Chlorine + ten atoms of water.

(136.) D. Chlorine and oxygen when mixed together have no mutual action; but if either of the elements be present in a nascent state, by which is meant, at the

instant of their disengagement from combination, a union may be effected. Part II.

In this manner four or five combinations with oxygen may be obtained. See subsects. 1, 2, 3, 4, and 5.

(137.) F. Unknown.

(138.) G. Chlorine unites with iodine, forming the chloriodic Acid. See sect. 4. subsect. 2 of this Chapter.

(139.) H. Chlorine unites with hydrogen, carbon, phosphorus, sulphur, selenium, and nitrogen. The compound with hydrogen is muriatic Acid, or as it is more properly termed, hydro-chloric Acid. See subsect. 6.

With carbon, Chlorine forms three combinations; the sub-chloride of carbon, the proto-chloride of carbon, and the hemideuto-chloride of carbon, called the perchloride, by Mr. Faraday, who discovered it. These compounds will be described in the section on carbon. Two chlorides of phosphorus exist, which will be described in sect. 5. So also for the chloride of sulphur, see sect. 6. For its union with selenium, see sect. 7. And for the chloride of nitrogen, (azotane,) see sect. 8.

(140.) I. The metals have in general a strong affinity for Chlorine; and it would seem that both true chlorides and chlorides of their oxides exist. In fact, every metal seems to be capable of uniting with Chlorine, and sometimes in more than one proportion. All these compounds are solid, with the exception of the deuto-chlorides of tin and arsenic, which are liquid and volatile. Many of the chlorides are crystalline powders. Generally speaking, the metallic chlorides are not decomposed by heat, but those of gold and platinum are so. The chlorides of the first two classes of metals are infusible below a red heat, and are not volatile. But those of the other metals are much more fusible, and frequently very volatile. All are soluble in water, excepting the chloride of silver and the proto-chloride of mercury: they for the most part absorb moisture with avidity. It appears, however, that in most cases their union with water is not a case of mere solution, but that a portion of the water is decomposed, so that its hydrogen unites with the Chlorine to form hydro-chloric Acid, while the oxygen goes to the metal, so as to produce a metallic oxide which, uniting with the hydro-chloric acid, produces a Salt. These phenomena are not, however, obvious in their progress, but it is very generally supposed that, in dissolving a metallic chloride, a solution of a hydro-chlorate is produced. and conversely, that in drying a hydro-chlorate sufficiently a metallic chloride is the result.

These generalizations, however, are not free from some exceptions, and some doubts which we have not space here to examine.

(141.) K. It is obvious that, strictly speaking, Chlorine has no action that can be referred to this division of our scheme.

(142.) L. The distinguishing properties of Chlorine are, that it has a greenish yellow colour: that it is unaltered by exposure to heat: that it immediately combines with mercury at ordinary temperatures: that it destroys vegetable colours. When present in a liquid, a white curdy precipitate is produced by nitrate of silver; which precipitate is insoluble in nitric Acid, but soluble in ammonia. A solution of the white of egg (*albumen*) produces a white flocculent precipitate composed of flexible and elastic fibres, which are insoluble in water and alcohol.

(143.) M. The first and most important use of Chlorine in the Arts is in *Bleaching*, which will form a por

**Chemistry.** tion of the applications of Chemistry to the Arts. This Gas is also the most powerful corrective or destroyer of noxious miasmata. For this purpose it has long been employed in lazarettos and hospitals. It forms the powerful ingredient in Labaracq's disinfecting liquor; where it is combined with lime or soda. This last preparation has only recently been introduced into this Country, under the name above mentioned; and we think that, in cases of infectious disease, even in private families, its use cannot be too strongly recommended.

*Subsect. 1.—Protoxide of Chlorine.*

(144.) All the combinations between chlorine and oxygen are held together by a very feeble affinity, and are, therefore, readily decomposed. Four are at present known, though from inadvertency two only are put down in our synoptic view. (4.) The atomic constitution of these, together with the circumstance just adverted to, would lead us to suppose that some intermediate combination may be found to exist whenever our means may be found sufficiently delicate for their detection. Indeed a fifth oxide is described by Count Von Stadion.

*Protoxide of chlorine* was discovered by Sir H. Davy in 1811, and was named by him *Euchlorine*. It is most readily obtained by placing two parts of the chlorate of potassa, one part of muriatic Acid, and one of water, in a small retort, and then applying a very gentle heat. The Gas evolved should be collected over mercury. A portion of chlorine is produced, but this unites with the mercury, while the protoxide of chlorine is collected pure.

The colour of this Gas is a yellowish green, but more vivid than that of chlorine. It has a smell something like that of burned sugar. Water will absorb eight or ten times its volume of this Gas. *Euchlorine* does not unite with alkalis. Like chlorine it discharges vegetable colours, but with less energy than the latter substance. It is so highly explosive, that the heat of the hand is sufficient to produce a separation between its constituents. Phosphorus, also, immersed in it, produces explosion and undergoes combustion. When exploded with hydrogen by the electric spark, water and muriatic Acid are the results. *Euchlorine* consists of two volumes of chlorine and one of oxygen. Its atomic constitution and Specific Gravity will be seen in the general Tables. (a.)

*Subsect. 2.—Tritoxide of Chlorine.*

(145.) The tritoxide of chlorine was discovered and is described by Count Von Stadion in Gilbert's *Annalen*. (b.) Some doubt, however, yet remains about this substance.

*Subsect. 3.—Tetartoxide of Chlorine. (Peroxide of Davy)*

(146.) The *tetartoxide of chlorine* was discovered by Sir H. Davy in 1815, and also by Von Stadion about the same period. About 50 or 60 grains of the chlorate of potassa is reduced to fine powder, and formed into a paste with strong sulphuric Acid. This paste is to be put into a glass retort, and then to be submitted to the heat of a water bath, not reaching so high as 212° of temperature. The Gas evolved is of a higher colour

than chlorine or its protoxide, having an aromatic odour without any smell of chlorine. It does not combine with mercury, but is absorbed by water in considerable quantity. It does not combine with alkalis, but it destroys vegetable blue colours without previously reddening them, in which respect it differs from the protoxide. Phosphorus introduced into it produces decomposition and undergoes combustion. By the experiments of Davy and Gay Lussac, it appears that 40 volumes of the Gas become 60 after explosion; and are then found to consist of 40 volumes of oxygen and 20 of chlorine.

*Subsect. 4.—Chloric Acid. (Pemptoxide of Chlorine.)*

(147.) *Chloric Acid* was first recognised as such in the chlorates, and pointed out by Mr. Chenevix. Its more careful examination was undertaken by M. Vauquelin (d.) and by M. Gay Lussac. (e.)

Vauquelin's process for obtaining it is as follows. To a solution of pure chlorate of baryta add, by degrees, diluted sulphuric Acid as long as any precipitation takes place. Thus the chloric Acid remains pure, combined with water only: care must of course be taken to add no more sulphuric Acid than is just sufficient to effect the separation of the baryta. The true point has been obtained when neither sulphuric Acid nor chlorate of baryta will produce a precipitate when added to separate portions of the Liquid.

The solution of chloric Acid thus obtained is colourless, having an acid or astringent taste. It reddens litmus: is volatilized by heat, but undergoes some decomposition in the process. It does not produce any precipitate from nitrates of silver, mercury, or lead. When chloric Acid and hydrochloric Acid are mixed together in just proportion, a complete decomposition is effected, chlorine and water resulting. It is decomposed by sulphuretted hydrogen or by sulphurous Acid, but none of the Acids which are saturated with oxygen have any action upon chloric Acid. It is also decomposed by all the metals which are capable of decomposing water, and chlorides of their oxides are produced. The constitution of chloric Acid is most generally supposed to be one atom chlorine + five atoms oxygen. (f.)

*Subsect. 5.—Perchloric Acid. (Heptoxide of Chlorine.)*

(148.) In obtaining the tetartoxide of chlorine by the process already given, (146.) a peculiar Salt was detected in the residuary matter by Count Von Stadion. It is found in octohedral crystals mixed with bisulphate of potash. These crystals are soluble in hot water, and also in 55 times their weight of water, at 60° Fahrenheit. It is insoluble in alcohol. By mixing this Salt with an equal quantity of sulphuric Acid, and distilling it at a temperature of 280° Fahrenheit, the salt is decomposed, and an Acid which has been called the perchloric may be distilled over. (g.)

*Subsect. 6.—Hydro-chloric Acid. (Muriatic Acid.)*

(149.) A. Professor Thomson is of opinion that by *Hydro-chloric Acid* was known to the alchemists, and states that it is mentioned in the writings of Basil Valentine. Glauber, he says, seems to have contrived the present mode of obtaining it by distillation from sulphuric



**Chemistry.** Acid and common salt. Mr. Cavendish first described the mode of obtaining it in the Gaseous form, in 1766. (A.) Priestley more fully described its properties. (i.) The experiments of Gay Lussac and Thenard (k.) tended to prove that muriatic Acid Gas is a compound of chlorine and hydrogen: and the further researches and reasoning of Davy went far towards establishing the same opinion, which is in fact now almost universally admitted. (l.)

Muriatic Acid exists, as has been already stated, (133.) in great abundance in the earth and in sea water, combined with alkaline bases: but in the state of a free Acid it does not seem to exist at all, unless, possibly, it may be evolved among the Gaseous products of active volcanos.

(150.) B. Hydro-chloric Acid, as it is commonly known and made use of, is a Liquid, consisting of the pure Acid Gas combined with water. This Gas is most readily obtained by putting chloride of sodium, (common Salt,) well dried, into a tubulated retort, and then adding to it strong sulphuric Acid. By applying the heat of a sand-bath, muriatic Acid Gas is evolved in considerable quantity. If this operation be conducted over mercury the Gas is obtained in great purity, but not without a considerable degree of hygrometric water. If, however, the beak of the retort be made to terminate in a receiver containing water the Gas is absorbed, and a strong liquid solution of the Acid is obtained. But in purposely preparing the liquid muriatic Acid, it is most convenient to employ a series of two or three Woulfe's bottles, having a small quantity of water in each, so that whatever Gas may escape from solution in the first bottle, can only pass on and be taken up by the Liquid in the second or third. The proportions recommended for this process are as follows: dried chloride of sodium eight parts; strong sulphuric Acid seven parts; water placed in the Woulfe's bottles five or six parts. The proportions recommended by the College of Physicians is two pounds troy of dry chloride of sodium; 20 ounces troy of strong sulphuric Acid mixed with half a pint of water. A pint of water is to be put into the receiver to absorb the Gas. For a very clear view of the rationale of this process for obtaining muriatic Acid, see Mr. Phillip's excellent and scientific translation of the *Pharmacopæia*.

Hydro-chloric Acid Gas may also be formed by the direct synthesis of its constituents. Thus, if equal volumes of chlorine and hydrogen Gases be mixed together in a bottle, and kept from the influence of light, no change is produced; but by applying a lighted taper, or passing an electric spark through the mixture, or even by exposing it to the light of the sun, combination is instantly effected. Mr. Brande found that the intense light from charcoal points, ignited by the Voltaic pile, were capable of producing the same effect: (m.) and Seebeck states that, among different colours, the blue rays of the spectrum are more effectual than those which are red. (n.)

Hydro-chloric Acid Gas, for experiment, may also be obtained by heating a little strong muriatic Acid in a retort over a spirit-lamp. This Gas, when quite dry, consists of one atom chlorine + one atom hydrogen, or 36 of the former + one of the latter by weight.

(151.) C. In the Gaseous state, hydro-chloric Acid has the following Physical properties. Its smell and taste are extremely pungent, and it is quite unfit for respiration. It is heavier than common air; the best esti-

mate of its Specific Gravity being 1.264866. (Thomson.) By heat alone it undergoes no change. Under a pressure of 40 atmospheres, and at a temperature of 56° Fahrenheit, it becomes a Liquid. It instantly extinguishes flame.

(152.) D. When oxygen and hydro-chloric Acid Gases are mixed together, and either passed through a red-hot porcelain tube or submitted to the electric spark, the chlorine is set free, and the oxygen unites with the hydrogen to form water. Dr. Henry states, that a similar decomposition is effected by inserting spongy platinum in the mixture at a temperature of 250° Fahrenheit.

(153.) E. No effect is to be expected under this head.

(154.) F. Unknown.

(155.) G. Iodine is slightly soluble in liquid hydrate of muriatic Acid, but with any action between the two substances in the Gaseous state we are not acquainted.

(156.) H. Muriatic Acid has no action on silicon, or its oxide silica. Neither has it upon hydrogen. Carbon is not soluble in it, but common charcoal will condense in its pores an enormous quantity of hydro-chloric Acid gas. We are not aware of any action between boron and this Acid. The same may be said of phosphorus, sulphur, selenium, and nitrogen.

Muriatic Acid possesses a very strong affinity for water: inasmuch that it is extremely difficult to obtain it quite free from that substance. When a lump of ice is admitted to a jar of muriatic Acid Gas confined over mercury, the ice liquefies as rapidly as if it had been placed in a fire. According to Dr Thomson, one cubic inch of water, temperature 69° Fahrenheit, will absorb 418 cubic inches of muriatic Acid Gas, producing an Acid the Specific Gravity of which is 1.1958. A useful Table has been given by Thomson, showing the quantity of real Acid in solutions of different Specific Gravities: it is calculated on the principle that, in forming a solution of marble in this Acid, every 50 grains dissolved indicate 37 grains of real Acid. See Part V. Table II.

(157.) I. As muriatic Acid is incapable of affording oxygen, it does not act energetically upon the metals: but by its determining power of affinity it induces many of the metals to decompose water when present, and thus to obtain oxygen. Such is the case with iron or zinc, when hydrogen is evolved. "When potassium, tin, or zinc is heated in hydro-chloric Acid Gas over mercury, the Gas undergoes decomposition, a metallic chloride is formed, and hydrogen is set free.

(158.) K. With other Acids the hydro-chloric cannot be said to act as a base, though some mutual actions take place on their admixture: these are generally instances of decomposition dependent principally upon either the affinities of oxygen and hydrogen for each other, or upon that of chlorine for the radical of the other Acid employed. Thus it is decomposed by the nitric, chloric, iodic, chromic, and molybdic, so that it cannot exist with these in the same solution.

Hydro-chloric Acid exerts a strong affinity towards metallic oxides, and decomposes many of their combinations with other Acids. The muriates, or, as we should more strictly call them, the hydro-chlorates, form a numerous and important class of Salts, which we shall have frequently to mention. All the true hydro-chlorates are neutral, and all contain water; for when, by great heat, this Liquid is driven off, they pass to the state of chlorides. All are decomposed by the sulphuric

**Chemistry** Acid, even when cold, and still more easily by the aid of heat. With heat the muriates are decomposed by the phosphoric, arsenic, and boracic Acids, when water is present. The nitric Acid has the same property in proportion to its strength.

(159.) L. The hydro-chloric Acid is recognised in a solution by its property of producing a white curdy precipitate with nitrate of silver, a test of very great delicacy. The precipitate thus produced is the chloride of silver, which should be well washed, dried, and fused in a glass vessel. In this state it contains one atom of chlorine + one atom of silver, or 36 parts of the former + 110 of the latter by weight, indicating 37 parts by weight of dry muriatic Acid.

(160.) M. In the Arts hydro-chloric Acid is frequently employed as a solvent; and, in Medicine it is given as a tonic. Dr. Prout made the singular discovery of its existence among the fluids of the stomach, sometimes in considerable quantity, in which case it seems to indicate a diseased action of that organ: and the mode of its production there appears extraordinary, since he could detect its presence in the stomachs of rabbits which had been fed on substances not apparently containing that Acid or its chief elementary constituent, chlorine. (v.)

(161.) We have adverted only slightly to the controversy that has existed between Chemists of first-rate excellence respecting the nature of chlorine and muriatic Acid. The one party having regarded chlorine as the simple elementary body, and muriatic Acid a compound formed by the addition of hydrogen: the other party having supposed muriatic Acid Gas the simple body, or at least that it consisted of an unknown radical united to oxygen; and that chlorine, or as it was by them termed, oxymuriatic Acid Gas, was a compound of oxygen with muriatic Acid Gas. The former, which is now the prevailing opinion, we have followed; but there is much in the controversial writings on this point that we strongly recommend to the attention of the Chemical reader, produced as they have been by the most distinguished Chemists of the Age. For this purpose consult reference. (p.)

#### References to § 2.

(a.) Davy, *Phil. Trans.* 1811. (b.) Von Stadion, *Thoms An. O.S.* vol. ix. p. 22. from Gilbert's *Annalen*, vol. iii. p. 197. (c.) Davy, *Phil. Trans.* 1815, Part II. (d.) Vauquelin, *An. de Ch.* vol. xcv. p. 102. (e.) Gay Lussac, *An. de Ch.* vol. xci. p. 111. (f.) *Ibid.* (g.) Von Stadion, *ut supra*. Gay Lussac, *An. de Ch.* vol. ix. (h.) *Phil. Trans.* vol. lvi. p. 157. (i.) Priestley, *On Airs*, vol. ii. p. 276. (k.) *Mém. d'Arcueil*, vol. ii. p. 307, 320, 322. (l.) *Phil. Trans.* 1809. (m.) Brande, *Phil. Trans.* 1820. (n.) Seebeck, *Nich. Jour.* vol. xxxiv. p. 220. (o.) Prout, *Phil. Trans.* 1824, p. 45. (p.) *Mémoires* by Dr. Murray and J. Davy, *Nich. Jour.* vol. xxxiv. Sir H. Davy, *Phil. Trans.* 1818, p. 169. *Trans. R. S. Edin.* vol. viii. *An. Phil. O.S.* vol. xii. p. 379. and vol. xiii. pp. 26, 285. Phillip, *An. Phil. N. S.* vol. i. p. 27.

#### § 3.—Fluorine.

**Fluorine.**

(162.) In assigning to Fluorine its present situation in our system, we acknowledge that we are acting upon supposition, and not upon fact. We are aware that in so doing we shall find the opinions of some very distinguished Chemists opposed to us; but after all, in a

matter confessedly undecided, we are willing to shelter ourselves from absolute censure, by saying that we only adopt the opinions of Sir H. Davy, advocated by Dr. Thomson, and perhaps by Berzelius also. On the whole, it seems to us the more plausible of the two generally proposed. It may be well just briefly to state that the one of these suppositions is, that Fluorine is a highly electronegative body, (analogous to chlorine,) and that by its union with Hydrogen Fluoric Acid is formed, which should, therefore, be called hydro-fluoric Acid. On the other supposition Fluorine is a base, (analogous to boron,) and that Fluoric Acid arises from the union of this base with oxygen.

(163.) A. Fluorine is so far from existing at all free in any part of the kingdom of Nature, that it has never yet been exhibited alone and uncombined by the utmost efforts of Chemical ingenuity. Fluoric Acid had long been suspected to be a compound of some unknown base with oxygen: but in 1810, M. Ampere was led by the analogy of chlorine to view it in the light of a compound of that base with hydrogen. This he communicated to Sir H. Davy, who published in 1813 and 1814 two very valuable papers in support of that opinion. To these papers we are indebted for the little that we know concerning the base of Fluoric Acid.

(164.) B. Sir H. Davy did not obtain Fluorine in a separate state, but the following were the modes by which he attempted to do so; together with the evidence which he obtained in favour of Ampere's and his own opinion. Potassium was added to Fluoric Acid, a violent degree of action ensued, hydrogen Gas was evolved, and a solid white residuum was obtained. Now, if it were certain that Fluoric Acid contained no water, we must infer that the Fluoric Acid underwent decomposition by the escape of its hydrogen, and that the white mass was a Fluoride of potassium. To ascertain whether the strong liquid Fluoric Acid (Specific Gravity 1.0609) contained water, Davy enclosed some in a platinum capsule within dry ammoniacal Gas, until it became saturated with that alkali. Thus dry Fluide of ammonia was obtained. According to the belief of Davy and Thomson, "when any Acid that contains water is combined in this manner with ammoniacal Gas, if we heat the Salt formed, water is always disengaged. Thus sulphuric, or nitric, or phosphoric Acid, when saturated with ammoniacal Gas and heated, give out always abundance of water." (Thomson.) Fluide of ammonia thus treated gave out no water. (a.) Upon this ground it seemed that Fluoric Acid contained no water.

The analogy with muriatic Acid seems plausible also. By heating potassium with muriate of ammonia, the Salt and its Acid are both decomposed. Chloride of potassium is formed, and the hydrogen and ammonia both escape, in the proportion of one volume of the former to two of the latter. So also if Fluide of ammonia be heated with potassium, a mixture of hydrogen and ammonia escapes containing precisely the same proportions as in the former case, and a solid white residuum is found and by analogy inferred to be the fluoride of potassium. (b.)

Again, by exposing Fluoric Acid to the Galvanic pile hydrogen was evolved at the negative wire, and the opposite wire, which was of platinum, was coated with a chocolate-coloured powder. (c.) When muriatic Acid is similarly acted upon, hydrogen is given out at the negative wire, and a chloride is formed round the extremity of the positive wire. Reasoning upon this



Chemistry. analogy, the chocolate powder would seem to be a Fluoride of platinum.

When Fluats of silver or fluats of mercury is exposed to the action of chlorine, and heated in a glass vessel, a metallic chloride is formed, the glass is corroded, and a quantity of Gas evolved, which is found to consist of oxygen and silicated Fluoric Acid Gas. In this case it is supposed "that the Fluorine is disengaged, that it immediately acts upon the silica in the glass, disengaging its oxygen and forming silicated Fluoric Acid, which may be considered as a compound of Fluorine and silicon." (Thomson.)

Such are the views of the able Chemist whose name has just occurred, in illustration of Davy's hypothesis. They seem to have much weight: but it may be fair to add that their accuracy has been questioned by other writers on this subject.

The attempts made by Davy to obtain fluorine separately, by repeating the last-mentioned experiment in silver or platinum vessels instead of glass, were always rendered unsuccessful by the Fluorine entering into combination with those metals respectively.

(165.) C. D. E. G. None, or unknown.

(166.) H. Of the substances under this head, the compounds of hydrogen, boron, and silicon, with Fluorine, are all that have yet been examined. These, as they form peculiar Acids, will form three subsections, to be noticed shortly.

(167.) I. We have already seen that Fluorine unites energetically with potassium, and also with platinum and silver; and may consider it probable that it will do so with every other metal. Those who entirely adopt Davy's views of Fluorine, will consider Fluor spar (or Fluat of lime, as it must be on the opposite creed) as a true Fluoride of calcium. Suppose a piece of this well-known and beautiful mineral to be acted upon by sulphuric Acid, which with the aid of heat is capable of effecting its decomposition. The water also of the sulphuric Acid is decomposed, its hydrogen unites with the fluorine to form hydro-fluoric Acid, which is one product, and its oxygen unites with the calcium to form the base of sulphate of lime, the other product.

(168.) K. L. M. Unknown.

#### Subsect. 1.—Hydro-fluoric Acid.

Hydro-fluoric Acid. (169.) A. Hydro-fluoric Acid has been long known by the name of fluoric Acid. The following is Thomson's summary of its history.

"Fluor spar, a well known mineral, is mentioned by Agricola under the name of fluor as a flux for metallic ores. (c.) Its property of corroding glass when mixed with sulphuric Acid was known at Nuremberg as early as 1670. The first attempt to ascertain the composition of this mineral was made by Margraaf. His experiments were published in the *Memoirs of the Berlin Academy* for 1768, but he informs us that they had been made in 1674. He reduced the mineral to powder, mixed it with its own weight of sulphuric Acid, and distilled it in a retort. He obtained a white, saline sublimate, and remarked with surprise that the retort was corroded into holes in several places. (f.) In the year 1771 Scheele published a set of experiments on fluor spar, in the *Memoirs of the Academy of Sciences of Stockholm*. He showed that the mineral was a compound of lime and of a peculiar Acid, to which he gave the name of fluoric Acid. He determined the

properties of this Acid, and showed it to differ from every other previously known. (g.) Dr. Priestley found that the Acids when obtained by Scheele's process, is a Gas possessed of peculiar properties, which he investigated and described. (h.)

"It was shown by Weiglib (i.) and Bachelz, (k.) and still more completely by Meyer, (l.) that the fluoric Acid of Scheele contained silica as a constituent; and Dr. John Davy ascertained the proportion of fluoric Acid and of silica that exist in the Acid of Scheele, and demonstrated that it is a peculiar compound of fluoric Acid and silica, in which the constituents always exist in the same proportions. (m.) Gay Lussac and Thenard, in 1811, published a method of preparing pure fluoric Acid, and were the first to determine its properties." (n.) Four fluates exist in Nature; the one already mentioned, fluat of cerium, double fluat of cerium and yttria, and the double fluat of soda and alumina, cryolite.

(170.) B. The method of Gay Lussac and Thenard is generally adopted. A retort and receiver of lead are made to fit well together. Into the retort put a quantity of pure fluor spar in fine powder, together with twice its weight of sulphuric Acid. Lute the apparatus, and apply a gentle heat to the retort; at the same time surrounding the receiver with a freezing mixture of snow and salt. The fluoric Acid is condensed in the receiver in the liquid form.

(171.) C. "At 32° Fahrenheit it is a colourless Liquid, like water. It does not congeal though cooled down to —4° Fahrenheit, and it remains a Liquid at 60° Fahrenheit. Its boiling point has not been determined, but it is low. When exposed to the air, it smokes violently, giving out a smell similar to that of muriatic Acid, but much stronger. It is very speedily dissipated in open vessels, and can only be preserved in metallic ones. The best are those formed of pure silver, and they must have a silver stopper which should be air-tight." (Thomson.)

This Acid, as obtained by Davy at its utmost concentration, was of Specific Gravity 1.0669. In this state he considered it quite free from water. If a drop of the Acid be let fall into water it combines with a hissing noise, like that which would be produced by red-hot iron; but when a few drops of water are poured into fluoric Acid ebullition is produced.

Fluoric Acid acts powerfully upon the animal system, the least drop acting as an escharotic, and producing a sore which is healed with difficulty. The fumes of it are repelled by the lungs with violence, and are so deleterious that scarcely the smallest portion can enter those organs with impunity.

(172.) D. The action of hydro-fluoric Acid upon the metals has been already noticed (163.) in connection with what we conceive to be the decomposition of this Acid to obtain fluorine. Its union with potassium and sodium, as examined by Thenard and Gay Lussac, is extremely violent, great heat, with effervescence, and the evolution of hydrogen, all resulting. Thenard states, also, that they tried three other metals, zinc, iron, and manganese. All three decompose the hydro-fluoric Acid with the evolution of heat and hydrogen Gas. M. Thenard considers it scarcely probable that any other metals, except those of his first two sections, and perhaps tin and cadmium, would produce any action upon this Acid. We have already stated our belief that fluorine will unite with every metal, but this is not opposed to M. Thenard's opinion, because it does not thence

**Chemistry.** follow that every metal will decompose the hydro-fluoric Acid for the purpose of uniting with its base, without some other determining agency; such, for instance, is Voltaic electricity.

(173.) E. Thenard states that the non-metallic combustibles, both simple and compound, have no action upon hydro-fluoric Acid.

(174.) E. and F. none.

(175.) G. none, or unknown.

(176.) I. none, or unknown.

(177.) K. With regard to the compounds formed by hydro-fluoric Acid with salifiable bases, we shall abridge the following general notice from Thenard's system.

The hydro fluates of ammonia is obtained by adding a dilute solution of ammonia to hydro-fluoric Acid, until the alkali be slightly in excess, and then evaporating by a gentle heat.

Of the metallic hydro-fluates there are twenty-one single ones already described, besides some double ones. Of these twenty-one, fifteen belong to the first three sections, and the six other are those of cobalt, copper, silver, lead, and mercury.

All these hydro-fluates are fusible by heat, provided they do not undergo decomposition. None of these Salts, if perfectly dry, could be decomposed by fire, but if humid, it is possible that many of them might undergo partial or total decomposition, because water has a strong affinity for hydro-fluoric Acid, and consequently in disengaging itself it might either wholly or in part carry off the Acid along with it. This effect is never produced upon the neutral hydro-fluates of the second section, nor on those of magnesia, silver, zinc, and iron, but it does take place with those of lead, cobalt, and copper, and they become reduced to the state of subhydro fluates.

With regard to the action of the simple combustibles upon the hydro fluates, much might be said, which entirely depends upon the theoretical view taken of the elementary body we are now describing. The relation existing between boron and this base has already been noticed, and it seems probable that combinations with other substances of this class may yet be discovered.

(178.) Water dissolves none of the metallic hydro-fluates at present known when in the neutral state, except those of potash, soda, and silver. But all are soluble in an excess of Acid.

(179.) The salifiable bases seem to unite with hydro-fluoric Acid through the medium of water in this order: lime, barytes, strontian, potash, soda, ammonia, magnesia, &c.

(180.) "The boracic Acid is the only one which is capable of decomposing the hydro-fluates *per se*, without the aid of water. If a mixture of two parts of fluor spar and one part of boracic Acid be heated nearly to redness in a bent gun barrel, we obtain a residuum of hydro-fluates of lime and boro fluoric (fluo-boric) Acid Gas. On the other hand, there are many Acids capable of decomposing the hydro-fluates through the medium of water; such are the sulphuric, the phosphoric, the arsenic. When a concentrated solution of these Acids is heated with a hydro-fluate in a leaden or silver vessel, there results a fixed sulphate, phosphate, or arseniate; and a compound of hydro-fluoric Acid and water, which is disengaged with effervescence, and disperses white pungent vapours through the atmosphere. Sulphuric Acid can even decompose many of these Salts at our ordinary atmospheric temperatures. Many also are de-

composed by the nitric, hydro-chloric, hydriodic, and especially by the hydro-sulphuric; but in no case by the sulphurous, nitrous, or carbonic Acids."

(181.) Silica has, like water, the property of facilitating the decomposition of the hydro-fluates. For example, if pure fluor spar be calcined with acid phosphate of lime in an iron tube, the vitreous Acid phosphate of lime does not decompose the fluor at the highest temperature. But if pure dry silica or sand be added, the decomposition takes place at a low red heat; and phosphate of lime, with a great quantity of silico-fluoric Acid Gas, are the results. From this experiment Thenard infers, that most of the hydro-fluates of the last four sections, which are not decomposable by charcoal at any temperature when dry, might easily be decomposed by that body if a quantity of silica were added to the mixture. (a) even it is probable that this might be effected by silica alone; for on the one hand, it would tend to unite with the metallic oxide, and on the other hand, with the hydro-fluoric Acid, and, indeed, it is not impossible that many fluates of the first two sections may be similarly affected, especially at very elevated temperatures.

(182.) If a solution of hydro fluates of ammonia, potash, or soda, be added to a solution of a Salt of barytes, strontian, lime, magnesia, alumina, zinc, iron, lead, mercury, &c. the insoluble hydro fluates of these bases are precipitated, at least if the solution be nearly neutral. But the soluble salts of glycina, yttria, and zirconia present some singularities. In fact, by adding a solution of hydro fluates of potash slightly acid to a solution of the hydro chlorate of each of these salts, all being slightly acid, we obtain on the one hand a precipitate of the neutral insoluble hydro fluates, and on the other, the soluble hydro-chlorate of potash sensibly alkaline. (c)

(183.) L. On this point we have little to add to that information which may be collected from the last article. The presence of hydro-fluoric Acid in a compound is usually recognised by decomposing that compound with sulphuric Acid, and allowing the escaping Gas to corrode glass. Berzelius has given modes for recognising it in mineral bodies in his *Essai de l'Employ du Chalumeau*, p. 159.

(184.) M. The only use to which the hydro-fluoric Acid has been applied is in the etching upon glass. This process is not difficult, and is sometimes very useful. Coat the glass with a thin but uniform layer of bees' wax, then write or scrape off the parts that are to be etched with some sharp instrument, so as to leave the surface of the glass quite exposed. Then mix some well pounded fluor spar with sulphuric Acid in a leaden or platinum crucible, and expose it to a moderate lamp heat. The hydro fluoric Acid Gas will escape in white fumes, and eat into the exposed surface of the glass. The wax may then be removed by heat and an indehible writing or etching is found upon the glass.

## Subsect 2.—Silico-fluoric Acid

(185.) By this term we mean the silicated fluoric Gas <sup>Silico-</sup> of Scheele, fluo-silicic Acid of Thomson, and fluates of <sup>fluoric Acid.</sup> Thenard. It may be said that, as we adopt Davy's and Thomson's opinions on the nature of this Acid, we ought to adopt Thomson's name for it. We by no means claim the right of introducing new names, a process ever replete with confusion, but if the compound of hydrogen with fluorine be called hydro-fluone

Chemistry. Acid, so also should the compounds of silicon and boron, being also Acids, be called silico-fluoric and boro-fluoric Acids. Witness also hydro-chloric Acid, hydriodic acid, hydro-sulphurous Acid, &c.

(186.) A. We now return to the acid compound of silicon and fluorine mentioned Art. (163.) a Gaseous body which does not exist naturally in its simple form. It was discovered by Scheele. (p.) Priestley examined it further; (q.) and Dr. John Davy published a paper on it in 1812. (r.)

(187.) B. To obtain this Gas, let equal quantities of fluor spar and glass, both in fine powder, be just formed into a paste with sulphuric Acid. This paste is to be exposed to a moderate lamp-heat in a small retort, which in this case may be of glass. The silico-fluoric Acid Gas will be evolved in considerable quantity, and may be collected over the mercurial trough.

Silico-fluoric Acid consists of

1 proportion silicon .	1.00	} Thomson.
1 proportion fluorine	2.25	
	3.25	

(188.) C. This Gas is colourless, has a smell much like that of muriatic Acid, has an acid taste, and reddens vegetable blues. It produces white fumes on mixing with atmospheric air. It does not support combustion, nor must any quantity, however small, be suffered to enter the lungs. Its Specific Gravity, according to Dr. Davy, is 3.5735, or 3.6111 according to Thomson. Water absorbs this Gas in great quantity, but at the same time the Gas suffers decomposition, and part of the silica is deposited. Heat alone is not capable of decomposing this Gas.

(189.) D, E, F, G. Unknown.

(190.) H. No substance from this class of bodies will decompose silico-fluoric Acid even with the aid of heat.

(191.) I. The metals of the last four sections have no action on this Acid at any temperature. But if potassium or sodium be placed in this Gas, and then heated, a violent action takes place, the Gas is absorbed, all metallic appearance is lost, and a chocolate-brown substance remains. When this substance is put into water there is a slight effervescence, hydrogen escapes, and hydro-fluates of silica and of potash or soda are formed.

(192.) K. Silico-fluoric Acid Gas unites with twice its volume of Gaseous ammonia, and forms a Salt which is volatile below a red heat, and from which water can separate some part of its silica; but if placed in contact with liquid ammonia, the whole of the silica separates, and hydro-fluate of ammonia is formed.

The silico-fluates of potash, soda, lime, and barytes, are formed by adding a solution of silico-fluoric Acid Gas in water to the solutions of these bases respectively; but it must be remembered that, in all these compounds, the silica exists in a smaller proportion than in the original Gas, as some portion of that earth will separate whenever the gas enters into union with water.

(193.) L. Nothing can be said on this point in addition to what is obvious from the properties already noticed.

(194.) M. None.

#### Subsect 3.—Boro-fluoric Acid.

(195.) A. Gay Lussac and Thenard first discovered

that boron united with fluorine to form a powerfully acid Gas. (a.) Part II.

(196.) B. The process for obtaining this Gas, recommended by Dr. J. Davy, is to mix fused boracic Acid in fine powder one part; fluor spar in powder two parts; and sulphuric Acid twelve parts. This compound is to be gently heated over a lamp, and the Gas collected over mercury; or by exposing mixture of boracic Acid and fluor spar in fine powder to a red heat in a gun-barrel. (L.)

(197.) C. Boro-fluoric Acid Gas thus obtained is colourless, has the smell of hydro-chloric Acid, reddens vegetable blues, and has an acid taste. Dr. Davy states, that water will absorb 700 times its volume of this Gas; it then becomes a highly Acid Liquid, capable of forming an ether when distilled with alcohol. It has no action upon glass; instantly carbonizes animal and vegetable substances; is not decomposed by a red heat.

(198.) D. When this Gas is mixed with oxygen no decomposition is produced; but it seizes with avidity any moisture that may be present, and thus forms white fumes of vapour. The same takes place with all other gases.

(199.) E. As with oxygen.

(200.) F. Unexamined.

(201.) G. Unexamined.

(202.) H. No simple composition has any action on this Gas.

(203.) I. Among the metals, those of the third, fourth, fifth and sixth classes will not decompose boro-fluoric Acid Gas. Its decomposition has, however, been effected by potassium and sodium. These metals, when heated in the Gas, burn almost as in oxygen; boron and fluoride of potassium or sodium result from that decomposition. When water is added, an alkaline hydro-fluate is formed in solution, and boron remains.

(204.) K. The combination of this Gas with ammonia is the only Salt of this Acid that has been examined. Of the boro-fluate of ammonia there exist three varieties; the first a solid opaque Salt; the second and third both are Liquids, though they contain no water: by exposure to the air they part with ammonia, and pass into the first variety. (L.)

(205.) L. The only application of this substance which has been suggested, is as a reagent, to detect moisture in other Gases, which it readily does, by the white fume formed when even only a very small portion of aqueous vapour is present.

(206.) M. None.

#### References to § 3.

- (a.) Davy, *Philosophical Transactions*, 1813, p. 268. (b.) *Ibid.* p. 269. (c.) *Ibid.* p. 271. (d.) *Ibid.* p. 275. (e.) *Geo. Agricola*, p. 458, Ed. Basil, 1558. (f.) *Collection Académique*, vol. xvi. p. 281. (g.) *Mémoires de Chymie de Scheele*, vol. i. p. 1. (h.) Priestley, *On Air*, vol. ii. p. 339. (i.) *Neues Entdeck. in der Chemie Th.* vol. i. p. 1—15. (k.) *Ut supra*, ref. (e.) (l.) *Schriften der Berliner Gesellsch. Naturf. Fr.*, vol. ii. (m.) *Philosophical Transactions*, 1812, p. 352. (n.) *Recherches Physico-Chimiques*, vol. ii. p. 1, &c. (o.) Gay Lussac and Thenard, *Recherches Physico-Chimiques*, vol. ii. p. 27. (p.) Scheele, *Mém. de Ch.* vol. i. p. 24. (q.) Priestley, *On Air*, vol. ii. p. 339. (r.) J. Davy, *Philosophical Transactions*, 1812, p. 352. (s.) Gay Lussac and Thenard, *Mém. d'Arcueil*, vol. ii. p. 317, and *Recherches*,

Chemistry vol. ii. p. 37. (1.) J. Davy, *Philosophical Transactions*, 1812, p. 363.

§ 4.—Iodine.

Iodine.

(207.) A. The discovery of Iodine resulted from an examination made by M. Courtois, a saltpetre-manufacturer at Paris, into the cause of the corrosion which took place upon the metallic vessels in which he separated soda from the ashes of sea-weeds. It was in 1812 that he thus detected this curious body and submitted it to MM. Clément and Desormes for further examination. The more complete inquiries into its nature were, however, made by M. Gay Lussac and Sir H. Davy, about the same time, viz. in 1813. The name Iodine was derived by M. Gay Lussac from *ιώης, violaceus*: a property belonging to it in the Gaseous state. There seems to be considerable variation in the quantities of Iodine produced from different species of sea-weed, obtained from different places. Dr. Fyfe has published an examination of several of these, from which he obtained Iodine by adding sulphuric Acid to very concentrated infusions of the *Alga*, (genus *Fucus*.) made by macerating them in hot water. (a.)

(208.) B. The marine plants that we have mentioned are collected in large quantities, and burned in heaps on the sea-shore. The ashes are collected and sold under the name of kelp to the soap-manufacturers for the sake of the soda that they contain. It is from this kelp that Iodine is most readily obtained. The process for which we are indebted to Dr. Wollaston is much the most commodious. The soluble part of the kelp is to be dissolved in water: evaporate the liquor so as to separate all the crystals that can be obtained. Pour off the remaining Liquid into a clean vessel, and add to it an excess of sulphuric Acid. By boiling this Liquid for some time sulphur is precipitated and hydrochloric Acid is driven off. Decant the clear liquor and strain it through wool. Then put it into a small flask, and mix with it as much black oxide of manganese as of sulphuric Acid used before. Apply to the top of the flask a glass tube, closed at one end. Then heat the mixture in the flask. The Iodine sublimes into the glass tube.

Dr. Ure obtained Iodine in considerable quantity from the waste ley which had been employed in making soap from Scotch kelp. (b.)

(209.) C. Iodine thus obtained is considered a simple body. It is solid at our ordinary temperatures. It is generally seen in small imperfect crystals of a lamellar structure; is of very slight tenacity; is of a blackish blue colour, with some metallic lustre; and has a good deal the appearance of a granular plumbago, or native sulphuret of antimony. By careful sublimation it is readily obtained in crystals, the primary form of which has been determined by Dr. Wollaston to be an octahedron, whose axes are nearly in the ratio of 2:3:4. (c.) Its Specific Gravity is 4.948 at temperature 62° 5 Fahrenheit, (d.) according to Thenard, but only 3.0844 according to Thomson. The taste of Iodine is acrid and hot, and its effects are poisonous. Its smell is like that of chlorine or chloride of sulphur. It is slightly volatile at even ordinary atmospheric temperatures: it fuses at 226° Fahrenheit, and boils at 347° Fahrenheit, but the colour of its vapour may be rendered obvious even at 100° Fahrenheit; and it entirely assumes the form of a beautiful violet coloured Gas much below 212° Fahrenheit, under the common atmospheric pres-

sure. It is not a conductor of Electricity, for if a small fragment be placed between wires, so as to form a part of the Voltaic circuit, the decomposition of water does not take place. Iodine is soluble in 7000 times its weight of water, but it is much more soluble in alcohol, and still more so in ether.

(210.) D. The union of oxygen with Iodine may be effected indirectly: and thus a peculiar proximate element is formed, the *Iodic Acid*. See subsect. 1. Iodine is, in fact, capable of expelling oxygen from both sulphur and phosphorus. Professor Sementini of Naples has discovered another compound of oxygen and Iodine which he calls Iodous Acid, but as yet its properties are little known. (e.)

(211.) E. Sir H. Davy formed the combination between Iodine and chlorine at Florence in 1814, and thus discovered *Chloriodic Acid*. See subsect. 2.

(212.) F. The direct union between Iodine and fluorine is of course yet unknown, but M. Gay Lussac examined the action between fluuate of potash (or fluoride of potassium) and Iodine: he says, "Sulphate of potash was not altered by Iodine, but what may appear astonishing, I obtained oxygen with the fluuate of potash, (fluoride of potassium,) and the glass tube in which the operation was conducted underwent corrosion. On examining the circumstances of the experiment, I ascertained that the fluuate became alkaline when melted in a platinum crucible. This happened to the fluuate over which I passed Iodine. It appears then that the Iodine acts upon the excess of alkali and decomposes it. The heat produced disengages a new portion of fluoric Acid or its radical, which corrodes the glass; and thus, by degrees, the fluuate is entirely decomposed."

(213.) H. Of the substances belonging to this division Iodine combines with hydrogen, phosphorus, sulphur, and azote. The affinity of Iodine for hydrogen is very considerable. It decomposes many substances in order to obtain it, and by the aid of heat, it is capable of absorbing a considerable quantity of this Gas. Thus is formed a peculiar Acid, the *Hydriodic*, to be described in subsect. 3.

(214.) Iodine and phosphorus unite when gently heated together in a glass tube over charcoal. The formation of Iodide of phosphorus takes place with increase of heat, but without the evolution of light. (d. p. 9.)

(215.) Sulphur unites with Iodine readily, but not with energetic action. Iodide of sulphur may be formed by combining the substances at a moderate heat; which heat, if again increased, readily produces their separation, and Iodine vapour escapes.

Iodine and carbon have not yet been united, nor have we any information respecting the action of Iodine with boron or selenium.

(216.) The compound of Iodine with azote was first formed by M. Courtois, by simply putting a quantity of Iodine into a solution of ammonia in water. A process of decomposition takes place, ammonia is decomposed, and the new compounds resulting are iodide of azote and hydriodate of ammonia. The latter remains in solution; the former falls down in the form of a black powder. In a quarter of an hour the process is complete and the Iodide may be washed upon a filter. This substance possesses violent detonating properties: when quite dry it will explode spontaneously; and when moist it will do so with only a very slight pressure.

Chemistry.

When this detonation is made in close vessels, azote and Iodine are found to be the sole products. (A.) (i.)

(217.) I. "Though as yet Iodine has been united only to potassium, sodium, zinc, iron, tin, antimony, bismuth, copper, lead, mercury, and silver, yet it appears that this substance possesses, like chlorine, the property of combining with all the metals. It is also certain that the Iodides are subject to the same law of composition with the chlorides and the sulphurets; for first, when they are placed in water they decompose it, and possess themselves of its two constituent elements, thus transforming themselves into hydriodates. 2. If we calcine the hydriodates of the protoxides of potassium, sodium, &c. the result is water and Iodides. 3. When the hydriodic Acid is placed in contact with oxides, and it decomposes them, there also result Iodides and water. The quantity of Iodine in the Iodides is therefore proportional to the quantity of oxygen in the oxides.

"All the Iodides at present known are solid, brittle, and scentless: the greater part have some flavour, and the greater part also crystallize: many are without colour. Among those that are coloured, many have a very deep tint. The Iodide of lead is a vivid yellow; the protiodide of mercury is a beautiful yellow; and the deutiodide is a vermilion red.

"Some Iodides are volatile: such as those of potassium, sodium, zinc, and mercury.

"All, excepting those of potassium, sodium, lead, and bismuth, are decomposed by oxygen at a red heat. Iodine is disengaged in violet vapours and the metal is oxidated. Some, like the Iodide of zinc, deliquesce by exposure to the air.

"When placed in contact with water, the Iodides of potassium, sodium, zinc, and iron decompose it instantly, and dissolve therein, passing to the state of hydriodates. It is probable that the same takes place with the remaining Iodides of the two first classes of metals.

"The Iodides of tin and antimony also effect, at common temperatures, the decomposition of water; but the hydriodic Acid does not unite to the metallic oxides: these are precipitated, while the Acid remains in the liquid.

"Those of bismuth, copper, lead, mercury, silver, and, in general, almost all those formed of metals which do not decompose water, are, on the contrary, inert when placed in it, and are not dissolved.

"Iodine is expelled from its combinations with metals by chlorine at a high temperature: but at such a temperature it has almost always an affinity for the metals superior to that of sulphur and phosphorus.

"Lastly, there is no Iodide known, wherein the concentrated sulphuric or nitric Acids cannot oxidate the metal and disengage the Iodine." (c. Art. 248.)

(218.) L. The mutual action between starch and Iodine is very striking. Stromeier asserts that a solution containing only 1-450000th part of Iodine produces a blue colour when mixed with a solution of starch. (f.) This colour varies from a delicate blue to a deep black, in proportion to the quantity of Iodine present. To ascertain whether a vegetable root contains starch, the root is cut transversely, and a drop of alcoholic solution of Iodine is let fall upon the cut surface; if the root contains any of that saccula of which starch consists, the drop exhibits a blue tint. Should the Iodine exist in a state of combination, it is

necessary to add a few drops of sulphuric Acid to disengage it, previous to the application of the test. With this reagent the presence of starch may be recognised in the solutions of some gums but not in those of others. By the help of this substance metallic palladium may be distinguished from metallic platinum. A drop of the tincture of Iodine is placed upon the polished surface and suffered to remain there. A black spot will be found upon both metals, but that upon platinum may be removed by heating the metal while that on palladium cannot.

(219.) M. Several preparations of Iodine have been recently introduced into Medical practice, for although this substance is an active poison, yet, as in many such cases, it may be exhibited in very small quantities: and the general opinion seems to be that it will form a valuable addition to the *Materia Medica*. On this head we can only direct our readers to M. Majendie's interesting Work. (g.) The most striking effects seem to have consisted in the dispersion of the goitre; and for this purpose it is now much employed in Switzerland.

#### Subsect. 1.—Iodic Acid. Oxiodic Acid of Davy.

(220.) A. This Acid is said to have been first recognised by M. Gay Lussac, but it was first obtained in a pure state by Sir H. Davy. It is entirely an artificial product, not having been found in Nature either in a simple or combined form.

(221.) B. To obtain Iodic Acid:—"Put 40 grains of Iodine into a thin, long-necked receiver. Into a bent glass tube, shut at one end, put 100 grains of chlorate of potash, and pour upon it 400 grains of hydrochloric Acid, of Specific Gravity 1.105: then make the bent tube communicate with the receiver and apply a gentle heat. Protoxide of chlorine is generated, which should be made to pass through dry chloride of calcium, in order to separate moisture. As soon as it meets with the Iodine two new compounds are formed: 1st, a compound of Iodine and chlorine—chloriodic Acid: and, 2dly, a compound of oxygen and iodine—oxiodic Acid. When heat is applied to this mixture, the chloriodic Acid, which is volatile, flies off, and the oxiodic Acid is left pure." (k.)

(222.) C. In this state it is a white semitransparent solid, without smell, but having a strongly acid flavour. In Specific Gravity it exceeds sulphuric Acid, as it will sink in that fluid. It first reddens and then destroys the colour of vegetable blues. It attracts moisture from the air slightly, and is very soluble in water. Such a solution gradually thickens by evaporation; then becomes pasty, and ends by remaining pure Iodic Acid. By a heat rather below the boiling temperature of olive oil it is decomposed into oxygen Gas and Iodine vapour. (d. p. 75.) and (k.)

(223.) D. E. F. G. unimportant or unexamined.

(224.) H. The combustible bodies exert a powerful action on Iodic Acid: for when it is heated with carbon, sulphur, resins, or sugar, a sudden detonation takes place.

(225.) I. The same effects are produced by many of the metals when they are in a state of minute division.

(226.) K. Iodic Acid unites with the sulphuric, phosphoric, nitric, and boracic Acids, forming crystalline compounds with the three first. It is decomposed by

Chemistry. the sulphurous, phosphorous, hydriodic and hydro-sulphurous Acids.

As an example of one these compounds: let sulphuric Acid be added drop by drop to a cold concentrated solution of Iodic Acid. A precipitate immediately takes place of *Iodo-sulphuric Acid*. This compound fuses when exposed to a gentle heat, and crystallizes, on cooling, in rhomboids of a pale yellow colour. By a more powerful heat, it is partly sublimed unchanged, and partly decomposed into oxygen, iodine, and sulphuric Acids. These compound Acids have such energy in their action upon metals as to dissolve even platinum. The Iodic and hydro-chloric Acids mutually decompose each other; producing water and chloriodic Acid.

With the saturable bases Iodic Acid forms Salts: and these when neutral are in general of very slight solubility. So great is its affinity for the oxides of lead and mercury, that it precipitates them both from their solution in nitric Acid. The iodates of ammonia, soda, potash, lime, barytes, strontia, zinc, and silver have been described. (n.)

(227.) L. See (215.)

(228.) M. None at present known.

Subsect. 2.—*Chloriodic Acid*.

Chloriodic Acid.

(229.) A. This substance, which is entirely an artificial production, was discovered about the same time both by Sir H. Davy and M. Gay Lussac.

(230.) B. Chloriodic Acid is formed by passing a current of chlorine Gas into a vessel containing iodine. The iodine absorbs the Gas and a yellow substance results, which by being fused with a gentle heat assumes an orange colour; but is red if the iodine be in excess. For the complete saturation of the iodine, this red substance must be dissolved in water, and then through this solution a current of chlorine is to be passed until saturation takes place. Solution of Chloriodic Acid thus formed is a clear liquid, provided neither of the elements be in excess.

(231.) C. It would seem from Davy's experiments that it is difficult to form Chloriodic Acid as a definite compound. When the chlorine is in defect the substance is solid, but when the quantity of chlorine is considerable, both substances seem to rise in vapour, though still in a state of combination. The solution has strongly acid properties and destroys vegetable blues.

(232.) D. F. H. Unexamined, or unimportant.

(233.) I. Chloriodic Acid seems to have a powerful mutual action with some of the metals, for it is decomposed by mercury which renders experiments upon this substance extremely difficult and unsatisfactory.

(234.) K. It seems impossible to combine this Acid with bases, for whenever such were presented to it, the water was decomposed, muriatic and iodic Acid being the result.

(235.) L. On this head consult Iodine L, and Chlorine L.

(236.) M. None at present; but Sir H. Davy, by feeding birds on bread soaked in the solution of this Acid, proved that it is not poisonous like pure iodine. (d. and h.)

Subsect. 3.—*Hydriodic Acid*.

Hydriodic Acid.

(237.) A. This Acid was doubtless first produced either during the experiments of M. Courtois or of MM

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Clement and Desormes, but its accurate examination was undertaken by M. Gay Lussac and Sir H. Davy. It would seem that the hydriodate of potash exists in the *Puci* only and in some of the Sponges.

(238.) B. Hydrogen and iodine if placed in contact enter into combination upon a moderate elevation of temperature. But there are other and better processes for obtaining Hydriodic Acid which depend upon presenting the hydrogen to the iodine in a nascent state. Of these we prefer the following. Put into a small tube retort eight parts of iodine and one of phosphorus, and let this mixture be slightly moistened with water. Then by the application of a very gentle heat the Hydriodic Acid comes over rapidly in the form of a Gas which may be collected over mercury, though mercury decomposes some of it: or it may be passed into water in which it is soluble, and may be kept for use as a test. Another excellent method is to diffuse iodine through water and then to pass a current of hydro-sulphuric Acid through the water: the hydrogen combines with the iodine, the Hydriodic Acid remaining in solution, and the sulphur is precipitated. Time should be allowed for the sulphur to subside, and any excess of Hydro-sulphuric Acid remaining in the liquid may be dissipated by the application of a moderate heat. In this manner, also, the Acid may with care be considerably concentrated. This Acid consists of one volume of iodine vapour + one volume of hydrogen.

(239.) C. Hydriodic Acid when pure is a colourless Gas, very acid to the taste, strongly reddening vegetable blues, and having a powerful smell, extinguishing combustion, and forming white fumes as it comes in contact with atmospheric air. Water absorbs this Gas with avidity, and by careful evaporation a solution of Specific Gravity 1.7 may be obtained. A red heat decomposes Gaseous Hydriodic Acid.

(240.) D. By admixture with oxygen Gas, Hydriodic Acid Gas is entirely decomposed. Water being formed, the iodine remains free.

(241.) E. By admixture with chlorine decomposition also takes place: the chlorine seizes upon the hydrogen to form hydrochloric Acid: and the iodine vapour gradually condenses into the solid form.

(242.) F. and H. Unknown.

(243.) I. Potassium, sodium, zinc, iron, mercury, and many other metals decompose this Acid: hydrogen is liberated, and metallic iodides are formed.

(244.) K. The hydrochloric, hydro-sulphuric, and sulphurous Acids do not affect the Hydriodic Acid when brought in contact with it, but concentrated sulphuric and nitric Acids cede a part of their oxygen to its hydrogen, so that from this double decomposition there results a deposit of iodine, sulphurous Acid Gas, or deutoxide of azote and water. Solutions of iron, also, in a high state of oxidation, throw down the iodine: as also some other metals which produce iodides.

There are also two compounds of the two varieties of phosphuretted hydrogen with Hydriodic Acid, and for these see (l.)

With bases the Hydriodic Acid forms Salts, which are all soluble in water, and for the most part crystallizable. For the properties of these we would refer our readers to Thomson's *Chemistry*, vol. ii. p. 277.

(245.) L. "Hydriodate of potash does not precipitate solutions of manganese, nickel, or cobalt. Hence the hydriodates of these metals are soluble in water. Gay Lussac is of opinion that all the hydriodates of the

Chemistry.

metals incapable of decomposing water are precipitated by hydriodate of soda. The precipitate of copper is greyish white; that of lead a fine orange yellow; that of protoxide of mercury greenish yellow; that of peroxide of mercury orange red; that of silver is white; that of bismuth moreen." Thomson. (m.)

(246.) M. None.

#### References in § 4.

(a.) Fyfe, *Edin. Phil. Journ.* vol. i. (b.) Ure, *Phil. Mag.* vol. i. (c.) Wollaston, *An. Phil. O. S.* vol. v. p. 237. (d.) Gay Lussac, *An. de Ch.* vol. xci. p. 7. (e.) Thenard, *Syst.* vol. i. (f.) Stromeyer, *An. Phil. O. S.* vol. vi. p. 312. and Gualtier de Claubry, *An. de Ch.* vol. xcii. p. 75. (g.) Majendie, *Essai sur la Préparation et l'Emploi de plusieurs nouveaux Médicaments*, Paris, 5th Edit. 1825. (h.) Davy, *Phil. Trans.* 1814, p. 86. (i.) Colin, *An. de Ch.* vol. xci. p. 262, and *An. de Ch.* vol. lxxxviii. and xc. (k.) Davy, *Phil. Trans.* 1815, p. 204. (l.) Dulong, *Mém. d'Arcueil*, vol. iii. p. 450; Houton Labillardiere, *Jour. de Pharmacie*, vol. iii. p. 454; Thenard's *Syst.* vol. i. p. 733. (m.) Thomson's *Syst.* vol. ii. p. 279, or Thenard's *Syst.* vol. ii. p. 637. (n.) Thomson's *Syst.* vol. ii. p. 274. (o.) *Quarterly Journal*, &c. vol. xvii. p. 381.

#### § 5. Bromine.

Bromine.

(247.) A. Bromine was discovered by M. Balard of Montpellier, (a.) who recognised it by a peculiar yellow cloud which appeared in the solutions from which he precipitated iodine by starch. These solutions were obtained from the lixivium of the ashes of the *Fuci*, which had been burned for the purpose of obtaining their alkaline matter; and also from the bittern left after the evaporation of sea water. M. Balard considers that this substance exists in small quantity in sea water as a hydro-bromate of magnesia. Also in marine plants growing on the shores of the Mediterranean; and in the shell of the *Ianthina Violacea*. M. Liebig has detected it in the saline springs of Theodorshall, near Kreutznach. (b.) Bromine is considered to be a simple substance, having properties intermediate between those of chlorine and iodine, which latter substance it ought to have preceded in our Synoptical Scheme. (†)

(248.) B. The best process for obtaining Bromine is to pass a current of chlorine Gas through the bittern or the lixivium of marine plants, and afterwards to agitate a little ether with the liquid. The Bromine is taken up by the ether, which assumes a deep hyacinth red colour, and by being left quiet for a short time rises to the surface. This solution is to be decanted off, and mixed with caustic potash; it thus becomes colourless, and cubic crystals of hydro-bromate of potash are obtained upon evaporation.

To obtain Bromine from these crystals, let them be reduced to powder and mixed with pure peroxide of manganese. Put this mixture into a retort with a little sulphuric Acid, diluted with half its weight of water; by gentle distillation vapours of Bromine are disengaged, which condense in red drops of liquid; or, to assist the condensation, a small quantity of water may be put into the receiver. The water may afterwards be entirely separated by distillation from dry chloride of calcium.

Bromine may also be obtained in its liquid state, though not perfectly pure, by simply distilling it from

the bittern after that liquid has been acted upon by chlorine as above described.

(249.) C. At ordinary temperatures Bromine is a liquid, of a blackish red colour in mass, but when in a thin film transmitting hyacinth red light. It congeals at about 0° Fahrenheit, (c.) and boils at about 116°.5 Fahrenheit. It is very volatile, emitting red vapours at ordinary temperatures; but it undergoes no change from either a red heat or from the action of the voltaic pile. It is absolutely a non-conductor of electricity. (d.) Combustion it will not support. It is soluble in water, alcohol, and readily so in ether. Like chlorine it discharges vegetable blues, but without reddening them. Its odour and taste are powerful and disagreeable, resembling chlorine. It corrodes animal matters, and produces a yellow stain on the skin, which shortly disappears; this colour is less intense than that produced by iodine. Specific Gravity 2.96. (Balard.)

(250.) D. No compound of Bromine and oxygen has been formed directly; and the only one that has been formed indirectly is the Bromic Acid. See subsect. 1. The affinity of Bromine for oxygen seems about equal to that which it exerts towards hydrogen; for oxygen cannot abstract hydrogen from Bromine; neither can Bromine decompose the vapour of water so as to possess itself of the hydrogen.

(251.) E. At ordinary temperatures Bromine unites with chlorine, producing a reddish yellow liquid, which is highly volatile, having a very penetrating odour and disagreeable taste. This liquid is soluble in water, apparently without undergoing decomposition. Alkalis when added to this solution decompose it, producing bromic and hydro-chloric Acids.

(252.) F. Unknown.

(253.) G. With Bromine iodine seems to form two combinations. The one a crystalline substance, the other a Liquid. Iodide of Bromine is soluble in water. By adding alkalis to this solution, iodates and hydro-bromates are produced.

(254.) H. The vapour of Bromine does not unite with hydrogen Gas by mere contact, but if a lighted candle or a piece of ignited wire be introduced into the mixture, combination takes place around the heated body, but without explosion, and without extending to the entire mass of the fluids. On mixing the vapour of Bromine with hydriodic Acid, hydro-sulphuric Acid, or phosphuretted hydrogen, they are respectively decomposed, and an Acid Gas, the hydro-bromic Acid, is produced. See subsect. 2. The affinity of Bromine for hydrogen is intermediate between the affinities of chlorine and iodine, for chlorine decomposes the hydro-bromic Acid; but Bromine will decompose the hydriodic Acid. Phosphorus unites with Bromine in two proportions; with sulphur in one proportion. M. Balard could not obtain a combination with pure carbon; but succeeded in forming a hydro-carburet of Bromine. M. Serullas has, however, succeeded in forming the Bromide of carbon. With selenium, Bromine has been also combined by M. Serullas.

(255.) I. With the metals the action of Bromine is much similar to that of chlorine. Antimony, tin, and potassium burn in it, the latter with great energy. M. Balard supposes that the soluble metallic Bromides are, like the soluble iodides and chlorides, converted into neutral hydro-bromates; and conversely, that the solutions of hydro-bromates are, by evaporation, converted

Part II.



**Chemistry** into anhydrous Bromides. The Bromides are all decomposed by chlorine, which unites with the metal setting the Bromine free. The attraction of Bromine for mercury is very strong, producing during combination considerable heat, but no light. M. Balard describes the Bromides of lead, mercury, silver, gold, and platinum: those of arsenic and bismuth are described by M. Serullas. (c.)

(256.) K. The only actions that can take place between Bromine and the Acids, is of the nature of decompositions: these, however, at present require further examination.

(257.) L. Bromine, or its combinations, produce no action whatever upon solutions of starch, by which it is clearly distinguished from iodine. An effort has been made to employ it as a test for all the vegetable alkalis; but complete success has not been obtained. (c.) The Bromate of potassa affords no precipitate with the Salts of lead; but a white one with the nitrate of silver, and a yellowish white one, soluble in nitric Acid with the proto-nitrate of mercury. By these characteristics it is well distinguished from the chlorate or iodate of the same alkali.

(258.) M. Bromine appears to possess poisonous properties; for by placing a drop of it upon the beak of a bird, the animal was destroyed.

#### Subject. 1.—Bromic Acid.

Bromic  
Acid.

(259.) When Bromine is agitated with a concentrated solution of potassa, or when the solid alkali is mixed with an ethereal solution of Bromine, two Salts, the Bromate and hydro-bromate of potassa, are formed. By evaporation, these are obtained in separate crystals; those of the hydro-bromate being cubic, and those of the Bromate acicular. The Bromate of potassa is separated from the hydro-bromate by being very sparingly soluble in cold water, while the latter is readily so. The Bromates possess properties analogous to those of the iodates and chlorates. Thus the Bromate of potassa when heated becomes Bromide of potassium, oxygen being disengaged; it deflagrates when thrown on ignited charcoal, and when mixed with sulphur it detonates upon percussion. The Acid of the Bromates is decomposed by substances that abstract oxygen, such as the sulphurous and hydro-sulphurous Acids. The Bromates also are decomposed by the hydro-chloric and hydro-bromic Acids.

The Bromic Acid is obtained in a separate state, by adding dilute sulphuric Acid to the Bromate of barytes. This Bromate may either be formed from the Bromate of potassa, or directly upon the general principle, that all the alkaline earths, except magnesia, seem to form with solutions containing Bromine the Bromic and hydro-bromic Acids, which may be separated as above described.

The Salts of lead produce no precipitate with solutions of Bromate of potassa, but abundant ones with the hydro-bromate of that alkali. M. Balard supposes the Bromic Acid to contain five atoms of oxygen + one atom of Bromine.

#### Subject. 2.—Hydro-bromic Acid.

Hydro-  
bromic Acid.

(260.) The action between bromine and hydrogen has been already noticed, (254.) but the best process for forming Hydro-bromic Acid is to mix together a small quantity of phosphorus and bromine in a retort; some moisture should be present; and by application

of a gentle heat Hydro-bromic Acid Gas is copiously evolved. This Gas may be collected over mercury or dissolved in water.

The Hydro-bromic Acid Gas has a pungent odour and an acid taste. On meeting with moist air, it produces very dense white vapours. It is not decomposed by being passed through a red-hot tube, even when mixed with oxygen. Chlorine immediately decomposes it, though iodine does not. Potassium decomposes it at all temperatures; and tin also when heated. Nitric Acid decomposes the watery solution of Hydro-bromic Acid with evolution of bromine; and the mixed liquid will dissolve gold. The alkalis, earths, the oxides of iron, and the peroxides of copper and mercury unite with Hydro-bromic Acid to form true Hydro-bromates; but with the oxide of silver and the protoxide of lead, a double decomposition takes place, producing a metallic bromide and water.

Iron, zinc, and tin dissolve in Hydro-bromic Acid; hydrogen being evolved. Hydro-bromic Acid consists of equal volumes of its two elements in the Gaseous state.

#### References in § 5.

- (a.) Balard, *An. de Ch. et Ph.*, vol. xxxii. p. 337. (b.) Liebig, *An. de Ch. et Ph.*, vol. xxxiii. p. 331. (c.) Serullas, *An. de Ch. et Ph.*, vol. xxxiv. p. 95; vol. xxxv. p. 340; and vol. xxxviii. p. 318. (d.) De la Rive, *An. de Ch. et Ph.* vol. xxxv. p. 160. (e.) D'Arcet and Chevruel, *An. de Ch. et Ph.*, vol. xxxviii. p. 82.

### CHAPTER III

#### Non-metallic (Electro-positive ?) Elements.

The substances which we shall consider in this Chapter are in number eight, exclusive of some important compounds, which will also be noticed as proximate elements; viz. silicon, hydrogen, carbon, boron, phosphorus, sulphur, selenium, and nitrogen. Of these, hydrogen and nitrogen are at present considered permanent Gases; but there is some reason to conclude from analogy, that, by enormous pressure, these and all Gaseous fluids might be reduced to the liquid form. The six remaining bodies are solid at our ordinary temperatures. Phosphorus, sulphur, and selenium are fusible and volatile; while silicon, boron, and carbon are generally considered as infusible and fixed. Not one of these has any action on oxygen at the ordinary atmospheric temperatures. Nitrogen has none at any temperature, however elevated; but hydrogen, boron, carbon, phosphorus, sulphur, and selenium are capable of combination with it, heat and light being evolved.

That silicon may be converted into an Acid is doubtful. Hydrogen is acidifiable by chlorine, fluorine, iodine, and bromine. Carbon, boron, phosphorus, and nitrogen by oxygen only; but sulphur and selenium by both oxygen and hydrogen.

#### § 1. Silicon.

(261.) A. The name Silicon has been proposed by Dr. Thomson (a.) for the base of the well-known earth silica. When Sir H. Davy first decomposed that body, he gave to its base the name of silicium, and such it continues with M. Thenard, and those who consider

**Chemistry.** this base entitled to rank among the metals. But if, with the greater number of Chemists, we consider this base analogous to boron and carbon, and destitute of metallic properties, Silicon is the more appropriate term.

"Sir H. Davy, after having succeeded in decomposing the fixed alkalis and alkaline earths by the action of the Galvanic battery, was naturally led to try the effects of the same powerful agent upon silica. But his experiments were not attended with success. (b.) But the analogy between silica and other bodies containing oxygen is so great, that it was universally considered as a compound of oxygen and a combustible base. Berzelius succeeded in separating this base from silica, and uniting it to iron, (c.) and his experiments were successfully repeated by Professor Stromeyer. (d.) About the end of 1813, Sir H. Davy succeeded in obtaining the base of silica in a separate state, although he was not able to collect it and examine its properties in detail." (e.) Thomson. (a.) Berzelius completed the evidence of the nature of this substance in 1824. (aa.)

(262.) B. Davy decomposed silica by passing excess of potassium through it in a heated tube of platinum. The potassium was converted into potash, through which the Silicon was disposed in the form of a dark-coloured powder.

Berzelius says nothing is more easy than to procure Silicon; the method by which it is obtained is this. The double fluato of silica with potassa or soda, heated almost to a red heat, for the purpose of driving off the hygrometric water, is introduced into a tube of glass closed at one end. Some fragments of potassium are introduced, and care is taken to mix the potassium with the powder, by applying a heat sufficient to fuse the metal, and gently tapping the tube. The heat of a lamp is then applied, and before the mixture arrives at a red heat there is a feeble detonation, and the Silicon is produced. The mass is then left to cool, and afterwards washed with water as long as any thing is dissolved. At first there is a disengagement of hydrogen Gas, because a silicuret of potassium is obtained, which cannot exist in water. The washed substance is a hydruet of Silicon, which at a red heat burns vividly in oxygen Gas; though the Silicon does not become oxidated. This hydruet is then to be put into a covered platinum crucible, and heated by slow degrees up to redness. The hydrogen becomes oxidated alone, and the Silicon will no longer burn in oxygen, though chlorine attacks it readily. A small quantity of silica is produced, which may be dissolved by fluoric Acid. If the Silicon has not been well heated to redness, the Acid dissolves it with slow disengagement of hydrogen. (aa.)

(263.) C. Silicon is a dark nut-brown powder, having no metallic lustre. It is a nonconductor of Electricity, and is infusible before the blowpipe.

(264.) D. Silicon does not burn in atmospheric air, or oxygen Gas, but it indirectly will form a very firm compound with that substance; thus producing the well-known earth silica, which exists in great abundance in Nature. See subject. 1.

(265.) E. Silicon readily unites with chlorine as already stated.

(266.) F. With fluorine, Silicon unites to form an Acid Gas which has been already noticed. (184.)

(267.) G. Unexamined.

(268.) H. Silicon unites with hydrogen, but its habits with other bodies of this class require investigation. **Part II.**

(269.) I. There is great reason to suppose that Silicon may unite with most of the metals, but as yet its combinations with iron and potassium are all that are mentioned.

(270.) K. Silicon is neither oxidated nor dissolved by the nitric, hydro-chloric, sulphuric, or fluoric Acids; but it is readily soluble in even a cold mixture of the nitric and fluoric Acids.

Silicon is not changed by being ignited with chlorate of potassa. It does not deflagrate in nitre, until the temperature is raised high enough to decompose the Acid; and then oxidation takes place in consequence of the concurrent affinities of oxygen for Silicon, and of silica for the disengaged potash. By a similar play of affinities, Silicon burns vividly when brought into contact with carbonate of potassa or soda, even below a red heat. When dropped upon fused hydrate of potassa, soda, or baryta, hydrogen is evolved with such rapidity as to produce explosion.

(271.) L. M. All that need be said on these heads will be found in subject. 1. L. and M.

#### Subject. 1.—Silica.

(272.) A. From the element silicon we proceed to its oxide Silica, which has long been known as one of the earths, and forms, in its various combinations with other mineral bodies, the largest proportion of the substance of our planet. "Quartz, chalcedony, flint, sand, and some other minerals consisting principally of Silica, have the property of melting into glass when strongly heated with potash or soda, and, therefore, were clasped together by the early Mineralogists under the name of vitrifiable stones. Mr. Pott, who first described the properties of these minerals in 1746, gave them the name of Siliceous stones, supposing them to be chiefly composed of a peculiar earth, called Siliceous Earth, or Silica. This earth was known to Glauber, who describes the method of obtaining it from quartz. But it was long before its properties were accurately ascertained. Geoffroy endeavoured to prove that it might be converted into lime, (f.), Pott (g.) and Beaume (h.) that it might be converted into alumina; but these assertions were refuted by Carthensier, (i.) Scheele, (k.) and Bergman. (l.) To this last Chemist we are indebted for the first accurate description (m.) of the properties of Silica." (a.)

(273.) B. Pure Silica is obtained by fusing pulverized flint with thrice its weight of caustic potash in a silver crucible. The spongy mass thus obtained is to be dissolved in water, and then super-saturated with muriatic Acid, and slowly evaporated to dryness. By subsequent affusion of water the alkaline Salt is removed, and the Silica remains pure.

(274.) C. Thus obtained Silica is a white powder, without taste or smell. Not soluble in water. "But when the compound of Silica and potash is dissolved in water, and sufficiently diluted, the Silica cannot be precipitated from it by any addition of Acid; showing that in this state it is really soluble in water." After it has been thoroughly dried it seems quite insoluble; but when fresh precipitated, and still moist, it dissolves, according to Kirwan, in 1000 parts of distilled water, and it exists naturally in minute proportions in some mineral waters, such as the Geyser springs in Iceland.

**Chemistry.** Silica is infusible, except by the heat of the Gas blow-pipe. It is not volatile under our ordinary processes, though it would seem from some observations of Bergman, and also from a more recent notice, that it is capable of volatilization by intense heat. (x.)

The crystallization of Silica forms a marked feature among its Physical properties. In Nature it is found in this state abundantly. There must be few who have not admired the beautiful hexagonal prisms of quartz, terminated by hexahedral pyramids, which occur in every Country of the Earth. This is rock crystal in its most common secondary form. We are frequently led to suppose that the process of the formation of crystals in the earth is a very tedious process, requiring the quiet operation of Ages to accomplish, but Chemistry offers many reasons to induce us to suspect that this may easily be overrated. The following confirmation of this view is taken from Thomson's *System*. "There are two methods of imitating these crystals by art. The first method was discovered by Bergman. He dissolved Silica in fluoric Acid, and allowed the solution to remain undisturbed for two years. A number of crystals were then found at the bottom of the vessel, mostly of irregular figures, but some of them cubes with their angles truncated. They were hard, but not to be compared in this respect with rock crystal. (y.) The other method was discovered by accident. Professor Seigling of Erfurt had prepared a *Liquor Silicium*, which was more than usually diluted with water, and contained a superabundance of alkali. It lay undisturbed for eight years in a glass vessel, the mouth of which was only covered with paper. Happening to look at it by accident, he observed it to contain a number of crystals, on which he sent it to Mr. Tromsdorf, Professor of Chemistry at Erfurt, who examined it. The liquor remaining amounted to about two ounces. Its surface was covered by a transparent crust, so strong that the vessel might be inverted without spilling any of the liquid. At the bottom of the vessel were a number of crystals, which proved on examination to be sulphate of potash and carbonate of potash. The crust on the top consisted partly of carbonate of potash, and partly of crystallized Silica. These last crystals had assumed the form of tetrahedral pyramids in groups: they were perfectly transparent, and so hard that they struck fire with steel." (z.)

(275.) D. E. None.

(276.) F. See (184.)

(277.) G. None.

(278.) H. None of the substances belonging to this class have any action on Silica.

(279.) I. Potassium and sodium are known to be capable of decomposing Silica, possessing themselves of its oxygen: the other metals have no action upon it.

(280.) K. It is under this head chiefly that we find the marked characteristics of Silica. It does not unite with Acids in general, from whence it would seem incapable of performing the part of a base: a strong argument against its being the oxide of a metal. There is, however, one Acid with which it manifests some singular properties, this is the hydro-fluoric, the only one capable of dissolving it. If finely powdered Silica be mixed with hydro-fluoric Acid the whole compound instantly assumes the Gaseous form. Silica fuses also into a Glass with solid phosphoric or boracic Acid.

On the other hand, Silica possesses strongly acid properties towards the alkaline bases, and on this

ground Mr. Smithson was led to consider it actually an acid body; and to argue that it performed the part of an Acid in its union with many earthy bases. In this view of the subject many mineral bodies are a sort of earthy Salts. (q.) This idea has been ably supported by Berzelius. (r.)

To proceed then to the combination of Silica with alkalis. It readily dissolves in solutions of either of the fixed alkalis, though ammonia has no effect upon it, either in the Gaseous or liquid form. When Silica is fused with potassa, if the latter be in great excess the compound is soluble in water forming the *Liquor Silicium* of old writers: but when the Silica is in great excess Glass is the resulting compound. Baryta seems to unite with Silica by fusion but imperfectly, though the affinity between the substances is considerable; for, according to Morveau, if barytic water be added to dilute *Liquor Silicium*, a precipitate is formed in which both earths are united. (s.) The compounds resulting from fusing these earths together in various proportions have been examined by Mr. Kirwan. (t.)

The habitudes of strontia with Silica are similar to those exhibited by barytes. "Equal parts of magnesia and Silica melt with great difficulty into a white enamel when exposed to the most violent heat that can be produced. (u.) They are infusible by inferior degrees of heat in whatsoever proportion they may be mixed. (v.)

If lime water be added to a solution of Silica in potash, a precipitate falls down containing the two earths in a state of combination. (w.) The compounds formed by fusing these two substances together, have been examined by Mr. Kirwan: (l. p. 56.) when the earths were in equal quantities an imperfect sort of enamel was formed. Silica has a strong affinity for alumina; for, according to Morveau, (s. p. 249.) if equal parts of Silicated potash and Silicated alumina, both in solution, be mixed together, a brown cloud appears, which by gentle agitation spreads throughout the whole Liquid. In the course of an hour this cloud gelatinizes. These two earths, however, cannot be heated so as to run into fusion. (v. and t.)

(281.) L. Silica is recognised by its insolubility in all Acids except the fluoric: by forming a compound entirely soluble in water upon calcination with twice its weight of potash in a silver crucible. The solution when concentrated forms a coagulum upon the addition of an Acid.

(282.) M. The uses of Silica are numerous and important. A variety of rock crystal, which occurs in rolled masses in the Island of Madagascar, being beautifully diaphanous, is cut for spectacles, and goes by the common name of crystal. The rich amethysts that come from Spain, Siberia, and Brazil, are only the same substance naturally coloured by the oxide of manganese. The manufacture of Glass will require a more extended detail in another part of this Work: for the present, therefore, we must be satisfied with stating, that two parts of Silica fused with from one to one and a half of carbonate of potash or soda, forms this most beautiful and useful substance. The more pure the ingredients the more clear will be the Glass; but as both the substances employed are not previously purified by the tedious and costly Chemical processes, the manufacturer is obliged to resort to other artifices for the improvement of his metal, as the fused compound is technically called. The finer kinds of Glass are made from pounded flint and the best pearl ash, or sometimes

**Chemistry.** fine washed white sand is used in place of the pounded flint. Window Glass is made from sand and kelp. Green bottle Glass is made from sea sand and the refuse of the soap-maker's lees, which contain a large proportion of lime. The less alkali is employed the harder is the Glass, but a greater heat is required for its fusion. Besides these, which are the essential ingredients, oxide of lead is added, which promotes the fusion of the materials; renders the Glass more dense and ductile, adds to its refractive power, and therefore to its brilliancy, and allows of its taking a higher polish.

Black oxide of manganese has been called the Glass-traker's soap, because it greatly improves the transparency of Glass. This it does by a mutual compensation of properties with the oxide of iron which is always present in both the main ingredients of Glass. For iron in a low state of oxidation gives to Glass a green tint, but in a high state of oxidation it either does not enter into fusion with the Glass, but is removed among the scoria, or when fused it does not communicate colour. On the other hand, the black oxide of manganese produces a violet colour; but in a lower state of oxidation it communicates no colour at all. When the two, therefore, meet in the formation of Glass, the iron gains some oxygen which the manganese loses, and both are reduced to that state which is most favourable to the transparency of the Glass.

By some variations in the composition, chiefly arising from the addition of several metallic oxides, certain kinds of Glass are formed in imitation of precious stones. The colourless variety is technically called paste, and by the addition of other metallic oxides all the coloured gems are imitated. (y.)

Porcelain also consists of various proportions of Silica and other earths fused together, but in this compound alumina predominates.

Enamels consist of Glass fused with large proportions of the oxides of tin and lead. (z.)

#### References in § 1.

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#### § 2.—Hydrogen.

Hydrogen.

(283.) A. With regard to the discovery of Hydrogen Gas, Dr. Thomson states that "Mayow, (a.) Boyle, (b.) and Hales procured it in considerable quantities, and noted a few of its mechanical properties. Its com-

bustibility was known about the beginning of the XVIIIth century, and was often exhibited as a curiosity. (c.) But Mr. Cavendish (d.) ought to be considered its real discoverer; since it was he who first examined it, who pointed out the difference between it and atmospheric air, and who ascertained the greatest number of its properties." (e.)

Hydrogen Gas is frequently generated in considerable quantities in mines, or in other parts of the Earth where metallic bodies exist. (f.)

(284.) B. Hydrogen Gas is readily obtained by acting upon iron turnings or small nails with sulphuric Acid, diluted with five or six times its weight of water. Granulated zinc may also be employed, in which case the dilute Acid may consist of eight-ninths of water. In both cases the metal is to be placed in a retort or glass proof, and the Gas, which is rapidly evolved, may be collected in jars over the water-trough. A very convenient instrument for obtaining and preserving a constant supply of this Gas in a laboratory was contrived by Gay Lussac, and is described in the *Annales de Chimie et de Physique*. (g.) Hydrogen Gas, however, thus obtained from metals, is not absolutely pure, (h.) and requires to be washed with a solution of caustic potassa. Berzelius discovered that Hydrogen Gas, procured from iron filings and dilute sulphuric Acid, might be deprived of all scent by being passed through pure alcohol; and that when the alcohol is diluted with water, and kept a few days, the odorous volatile oil is separated. (i.) Hydrogen Gas may also be procured in very considerable quantities by passing the vapour of water over coils of iron-wire heated to redness in a gun-barrel: the iron undergoes oxidation and the Hydrogen is set free.

(285.) C. Pure Hydrogen Gas is free from smell and taste. Water will absorb only about two per cent. of its own volume. It is unaltered by heat and electricity. Its action on the rays of light is more highly refractive than that of any other Gas. It is inflammable, and the lightest of all known substances. It will not support animal life, though its properties do not seem to be poisonous. When breathed from a bladder or oil-silk bag, it renders the tone of the voice of a much higher pitch than usual: an effect, which shortly goes off again. (p.)

The combustion of Hydrogen with oxygen affords many interesting particulars, for the full details of which we can only point out the references. (k.) Water is the sole produce of this combustion, subsect. 1. The proportion in which these two elements unite is precisely two volumes of Hydrogen + one volume of oxygen.

When Hydrogen Gas, issuing from a small orifice, is burned in common air, and a glass tube is held over the flame, musical sounds are produced. (m.)

(286.) D. Hydrogen and oxygen do not unite when merely placed in contact with each other, but by violent compression. M. Biot found a mixture of these Gases might be made to unite. The combination took place with evolution of light and heat. Biot also found that a pressure of thirty atmospheres, produced (by sinking a vessel of the mixed Gases to a depth of one hundred and fifty fathoms in the sea, did not cause their union. (n.)

The combination of these Gases may also be produced by the electric spark, by a glowing coal, or a red-hot wire; but if the heat of these bodies be below redness, the combination takes place gradually and silently. When the Gases are in the just proportion to form water, the

**Chemistry.** detonation is very violent: upon this combination depends the eudiometer of Volta, and the Philosophical experiment of the air-pistol.

Döbereiner discovered that the sub-oxide of platinum, and also the pulverulent metallic platinum, obtained by heating the ammonia-muriate, would, if plunged into the mixed Gases, condense the Hydrogen in its pores so violently as to become red hot, by which means instantaneous combustion is produced. It has been proposed to employ this method also for eudiometry. (l.) Upon this property is founded an elegant instrument for obtaining an instantaneous light.

The intense heat developed by the combustion of Hydrogen with oxygen has been applied to the construction of a blowpipe for the fusion of refractory bodies, and there is scarcely any substance in Nature that can resist its action. See BLOWPIPE, in the Miscellaneous department of this Work, or Professor Clarke's *Treatise on the Gas Blowpipe*. (o.)

Hydrogen and oxygen may also be made to unite in a proportion different from that in which they form water. See subsect. 2.

(287.) F. The union of Hydrogen with chlorine producing hydro-chloric, or as it has long been called, muriatic Acid, has been already noticed, chap. ii. sect. 2. subsect. 6.

(288.) F. See chap. ii. sect. 3. subsect. 1.

(289.) G. See chap. ii. sect. 2. subsect. 3.

(290.) H. Hydrogen unites with carbon, phosphorus, sulphur, selenium, and nitrogen. These compounds, as they form proximate elements, will for the most part be described at length hereafter.

(291.) I. Hydrogen forms with potassium two compounds; the solid hydruret discovered by MM. Gay Lussac and Thenard, (q.) and also a Gaseous compound described by M. Sementini of Naples. With arsenic, also, two analogous compounds are formed: the one solid, the other Gaseous. Tellurium forms with Hydrogen two compounds; the one Gaseous, *Telluretted Hydrogen*, which has acid properties, (r.) the other a white powder discovered by Ritter, but at present little known.

(292.) K. At ordinary temperatures Hydrogen does not act upon the metallic oxides; nor indeed at any temperature on those of the first class of metals. At a heat below redness, it reduces all the higher oxides of the second class of metals to the state of protoxides. At different degrees of heat it reduces all the oxides of the other classes to the metallic state; the products being the pure metal and water.

(293.) L. Hydrogen is principally recognised by its property of combustibility, and by its union with oxygen, determinable by the electric spark in Volta's eudiometer.

(294.) M. None.

*Subsect. 1.—Water.*

**Water.**

(295.) The Chemical history of this well-known and essential substance, formerly called one of the four elements of the Earth, possesses considerable interest; both with regard to its actual properties, and the elaborate researches to which it has given rise.

Pure water is a colourless Liquid, having neither scent nor taste. It refracts light very strongly, is an imperfect conductor of electricity, and a very slow conductor of heat. It is now admitted to be a compressible fluid. (68.) Its Specific Gravity is called one,

being made the unit of the scale to which the gravity of all other solid and liquid bodies is referred. Water is obtained in the greatest purity by slow distillation; but it is also sufficiently pure for many purposes when procured by melting snow, or by collecting rain water at a distance from houses or large towns. One cubic inch of water at 60° Fahrenheit and 30° in Ber. weighs 252.525 grains. Its weight is 828 times that of an equal volume of atmospheric air under the same circumstances.

The decomposition of Water may be effected in various ways. By submitting it to the action of a Voltaic battery, the two constituent Gases oxygen and hydrogen may be obtained separately. The same may be performed by a current of electricity from the common electrical machine. (s.)

The hydrogen may be obtained in the Gaseous form by passing steam over coils of iron-wire made red hot in a gun-barrel, or in a porcelain tube. In this case the oxygen assumes the solid form in combination with the iron.

To obtain the oxygen Gas alone, let a few sprigs of mint be placed in an inverted jar filled with Water over the pneumatic trough; as long as the vital functions of the plant are going on hydrogen is taken up by its leaves, pure oxygen Gas is evolved, and is collected in the jar.

The converse operation of the synthesis of Water is effected by mixing together oxygen and hydrogen Gases, and then applying a lighted taper, a piece of spongy platinum, or by passing an electric spark through the mixture. This experiment requires care, as the detonation of the mixed gases is very violent.

The just proportion, so as to leave no residuary Gas, is one volume of oxygen Gas + one volume of hydrogen Gas. If a jet of hydrogen Gas be lighted, and then an empty glass-balloon be inverted over it, the Water that is formed by its union with oxygen will condense in drops of Water on the sides of the balloon. It is now generally admitted that Water consists of precisely two volumes of hydrogen combined with one volume of oxygen, or by weight eight parts of oxygen + one part of hydrogen; or, according to the present views of the atomic theory, of one atom of each of these elements. The atom of Water, therefore, upon the hydrogen scale = 9

Water generally contains within its pores atmospheric air; and it is capable of absorbing various proportions of the different Gases. (t.) It exists also at all times in the atmosphere in the state of vapour; the quantity differing greatly at different temperatures. Pulverulent substances also absorb and retain considerable quantities of aqueous vapour. (u.) Water is one of the most universal solvents in Nature. It enters also frequently into combination with other substances, and assumes the solid form; of this the slaking of lime, is an example; as also the common hydrates of potash, soda, &c. which, in appearance, are quite dry. The point at which Water has its maximum density is generally stated to be, 39° Fahrenheit, but M. Biot places it at 38°.16 Fahrenheit. (v.) It congeals at 32° Fahrenheit, and boils at 212° Fahrenheit, Ber. 30°, but it rises in vapour at much inferior degrees of temperature.

*Subsect. 2.—Deutoxide of Hydrogen*

Deutoxide of Hydrogen.

(296.) This substance was discovered by M. The-

Chemistry. nard in July 1818. It is obtained from the peroxide of barium by a process of such delicacy, that it would not be possible to give, in the limits to which we are confined, any serviceable outline of it. We must, therefore, refer to the original *Memoirs* of M. Thenard. (w.)

The Deutoxide of Hydrogen is limpid, like water; has scarcely any smell. It gradually destroys the colour of papers stained with vegetable blues. It readily attacks the epidermis, whitens it, and causes a pricking sensation, the continuance of which varies in different individuals. Applied to the tongue it produces similar effects, together with a sort of slightly metallic taste. The elastic force of its vapour is much less than that of water, at any given temperature. It will entirely rise in vapour, even at low temperatures, though but slowly. Thenard was not able to freeze this Liquid by any degree of cold that he could produce. It must always be kept surrounded with ice, for it decomposes rapidly at a temperature of 58° Fahrenheit; and the heat of boiling water is sufficient to produce an explosion from the rapidity of the decomposition. The Specific Gravity of this Liquid is 1.425. It will mix with water, but if poured gently into that Liquid it passes through it like sirop. From the analysis of M. Thenard it appears that the Deutoxide of Hydrogen contains twice as much oxygen as the protoxide; that is to say, two atoms of oxygen = 16 + one atom of hydrogen = 1, so that the weight of its atom = 17.

Light does not produce any very marked change upon this Liquid. The metals act upon it variously: some abstract a portion of its oxygen and reduce it to the state of water; others set a part of the oxygen free and take the remainder into combination; while others liberate all the oxygen without possessing themselves of any of it; and a few seem to possess no action upon it whatever. The Acids, especially the stronger ones, render the combination between its elements more firm. By the Voltaic pile it undergoes decomposition like water, as must be expected.

#### References to § 2.

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p. 118. (v.) Biot, Thomson's *An.* vol. ix. p. 434. (w.) Thenard, *An. de Ch. et Ph.* vols. viii. and ix. or *An. Phil.* N. S. vols. xiii. xiv. xv.; *Qu. Journ.* vols. vi. and viii.; *Mem. Acad. Par.* 1818; or Thenard *Syst.* Ed. 5. vol. ii. p. 42.

Part II.

#### § 3.—Carbon.

(297.) A. Carbon is seen commonly in two forms; both which consist of this element in considerable purity, common charcoal, and the diamond. Unlike as these two substances appear to each other, it has not yet been proved that they differ, except in the state of their aggregation. Newton, by a beautiful generalization deduced from Optical properties, suspected the presence of a combustible principle in the diamond. The experiments of the Florentine Academicians, in 1694, and those of others made subsequently, confirmed his supposition. (b.) Guyton first showed that the combustible principle was Carbon. (a.) Numerous experiments of this sort were made in different parts of Europe: of these, the best were by Mr. Tennant, the late Professor of Chemistry in the University of Cambridge, Messrs. Allen and Pepys, and Sir H. Davy; and all tended to prove that, in the combustion of the diamond, oxygen is taken up, and that a Gas consisting of this substance combined with Carbon is the product. (c.) Carbon exists, also, in considerable quantity in plumbago, a mineral consisting essentially of this substance combined with a small quantity of iron. It forms the chief element in all vegetable matter, and exists in various proportions in several animal substances.

Carbon.

(298.) B. Charcoal is generally now obtained by burning heaps of fagot wood in a sort of stack covered with turf, or still better by distilling the wood in cylindrical iron retorts: one product obtained by this method is the pyroligneous Acid, sold as vinegar and possessed of valuable antiseptic properties. (d.) *Lump black* is a sort of charcoal, being the soot collected by burning the refuse resin procured in making turpentine. *Ivory black* is the carbonaceous matter obtained by the incineration of bones. *Coke* is a sort of impure charcoal, obtained by the close combustion of coal; and contains sulphur with much earthy matter. Charcoal for Chemical purposes may be obtained by burning box or alder-wood, or pieces of leather in a crucible covered with sand. It may be had in still greater purity by incinerating sugar or starch, or by passing the vapour of turpentine or spirit of wine through a red-hot porcelain tube. Carbon is at present deemed a simple ultimate element.

(299.) C. Carbon is a solid, even at the greatest elevations of temperature that we can command in our furnaces; still it seems proved, that by the powers of the Gas blowpipe it may be fused. And some recent experiments made with the Galvanic deflagrator by Professor Silliman and others, seem to attest that it is capable both of fusion and volatilization. (e.) Charcoal is a slow conductor of caloric, but conducts electricity readily. The Specific Gravity of the diamond is 3.52. The Specific Gravity of charcoal is generally stated much below the truth, in consequence of the porous nature of that substance; but recent experiments, in which that source of error is obviated, have assigned to it a Specific Gravity, equal at least to that of the diamond.

**Chemistry.** Pure Carbon is insoluble, and has neither smell nor taste. Charcoal, in consequence of its numerous pores, is capable of absorbing and even condensing within itself very considerable quantities of Gaseous fluids; but these quantities differ for different Gases. On this point the experiments of Saussure seem the most satisfactory; but others will be found by reference. (f.) It has also a great tendency to absorb moisture from the atmosphere, and in this respect the different woods vary in their powers. (g.)

(300.) D. In atmospheric air charcoal will just burn, but a small piece will not keep up a state of combustion without a current of air, or the aid of adventitious heat. In oxygen, however, a piece of charcoal, heated previously, burns with vigour. The diamond will burn in atmospheric air when heated by a muffle; and in oxygen Gas it continues to support its own combustion, if previously heated by being placed in the focus of a lens. It burns, also, by being thrown into melted nitre. The produce of this combustion is Carbonic Acid. See subsect. 2. With oxygen, also, another compound may be formed, to which the name of Carbonic oxide may be given. See subsect. 1.

(301.) E. If charcoal be ignited in chlorine Gas no combination is produced, but by an indirect process Mr. Faraday succeeded in forming two chlorides of Carbon, and another such combination has been subsequently discovered.

Olefiant Gas consists of one atom Carbon + one atom hydrogen. If this Gas be mixed with an equal volume of chlorine, the three elements all unite. From this compound the hydrogen may be abstracted by treating it with more chlorine, and a true chloride of Carbon results. For the minutiae of the process we must refer to Mr. Faraday's *Memoir*. (h.) This substance Mr. Faraday calls the *Perchloride of Carbon*. It is a solid, pulverulent, or crystalline substance, having an odour something like that of camphor. Its refractive power is greater than that of flint glass. Specific Gravity about 2.0. It does not conduct electricity. Its melting point is  $320^{\circ}$  Fahrenheit, and it boils at  $360^{\circ}$  Fahrenheit. It is scarcely soluble in water, but dissolves in ether or alcohol, and in both the fixed and volatile oils. In the flame of a spirit-lamp it burns with a red light, and supports a vivid combustion in oxygen Gas. It is not readily affected by either Acids or alkalis, but the metals decompose it, abstracting its chlorine. Chlorine Gas does not affect it, but iodine and hydrogen decompose it. Its composition is stated at three atoms of chlorine + two atoms of Carbon.

(302.) By passing the vapour of the substance just described over fragments of rock crystal in a red-hot glass tube, a partial decomposition is effected; one portion of chlorine escapes, and a liquid *Chloride of Carbon*, containing one atom of each of its elements, condenses in the cooler parts of the tube. The Specific Gravity of this fluid is 1.5526. Its refractive power 1.4875. It is perfectly limpid, and is not combustible *per se*, but burns in the flame of a spirit-lamp. It remains fluid at  $40^{\circ}$  Fahrenheit; rises in vapour between  $160^{\circ}$  and  $170^{\circ}$  Fahrenheit. It does not mix with water, but dissolves in ether and alcohol; is unaffected by Acids or alkalis; but is decomposed at high temperatures by oxygen, hydrogen, and the metals.

(303.) The *sub-chloride of Carbon* was brought to England from Sweden by M. Julin of Abo, in Finland, where it had formed accidentally during the distillation

of nitric Acid from nitre and sulphate of iron. (i.) This substance is in the form of soft white fibres, insoluble in water; not acted upon by boiling Acids or alkalis; soluble in heated turpentine, and also in alcohol; but most of it again separates in a crystalline form as the Liquid cools. It sublimes slowly at  $250^{\circ}$  Fahrenheit; but fuses, boils, and is volatilized between  $350^{\circ}$  and  $450^{\circ}$  Fahrenheit. Potassium burns in its vapour, with deposition of the Carbon. It is decomposed by passing over fragments of rock crystal heated to redness. From the analysis of Messrs. R. Phillips and Faraday, it appears to consist of one atom chlorine + one atom Carbon.

(304.) *Chloro-carbonic Acid*. This name is now applied to a Gas called by Dr. Davy, its discoverer, *Phosgene Gas*, from the mode of its preparation. When equal volumes of chlorine and Carbonic oxide Gases are made perfectly dry and exposed in a flask for a quarter of an hour to bright sunshine, the green colour disappears and a condensation of one half the volume takes place. This Gas has a very pungent odour, reddens litmus paper, is decomposed by water into muriatic and Carbonic Acid Gases. It forms a Salt with ammonia: thus affording the rare instance of a simple base united to two acidifying principles. Its constitution is one atom Carbonic oxide + one atom of chlorine. (k.)

(305.) F. Unknown.

(306.) G. Undiscovered. (l.)

(307.) H. With the substances under this head Carbon forms most important combinations, which will for the most part be noticed hereafter. The compound of Carbon with nitrogen is called *Cyanogen*. See sect. 8. subsect. 7. Its combinations with hydrogen will be found in subsect. 3, 4, 5, 6, 7, and 8, and a curious substance formed by its union with sulphur, in sect. 6. subsect. 7.

(308.) I. With the metals Carbon forms several compounds. Those with iron are of first-rate importance in the Arts. Plumbago has been already mentioned. Steel, in all its various forms, consists essentially of iron united to Carbon.

(309.) K. The distinguishing characteristics of Carbon are, that it is solid, insipid, inodorous, fixed under ordinary processes, and (the diamond excepted) black. By combustion with oxygen it forms Carbonic Acid, a substance readily recognised.

(310.) L. The uses of Carbon are as a fuel; in the manufacture of gunpowder; as a pigment; in the formation of steel; for the production of coal Gas for the purposes of illumination; as a polishing powder. It has also a very singular power of depriving many substances of colour, and of rendering them inodorous. The principle of its action in these cases is by no means well understood. (m.) It is highly antiseptic, and hence it forms a good tooth-powder; it will remove the smell from tainted meat; and water may be preserved pure in long sea voyages by charring the inside of the casks. (n.)

#### Subsect. 1.—Carbonic Oxide.

(311.) The discovery of this Gas was made by Dr. Priestley, who obtained it from the distillation of charcoal with Oxide of zinc. Its properties were more fully developed, by Mr. Cruickshank, (o.) and subsequently by MM. Clément and Desormes. (p.) The associated Dutch Chemists proposed a different view of its nature, (q.) which, however, has proved erroneous. It may be obtained:—



Chemistry.

1. By distilling one part of charcoal with eight parts of Oxide of zinc in an earthen or coated glass retort. Finery cinder, which is iron in a low degree of oxidation, may be used instead of the Oxide of zinc.

2. By transmitting Carbonic Acid Gas over ignited charcoal in a porcelain tube: a convenient apparatus for the purpose is described by M. Bernel. (r.)

3. By distilling dry Carbonate of lime or barytes, with one-fifth its weight of charcoal, or with dry iron, or zinc filings.

The Gas so obtained must be purified by agitation with lime water, or solution of a caustic alkali.

Carbonic Oxide has an unpleasant smell: it is inflammable, burning with a blue flame. Mixed with half its volume of common air it forms an explosive compound, which may be ignited by a hot wire, or a piece of lighted charcoal. It is lighter than common air. Its action with oxygen, when in contact with spongy platinum, is described by Dr. Henry. (s.) This Gas is but slightly soluble in water, and does not cause any precipitate in lime water. It is noxious to animal life. (t.) When 140 measures of Carbonic Oxide + 50 measures of oxygen Gas are fired by electricity in Volta's eudiometer, 100 measures of pure Carbonic Acid result. Carbonic Oxide is decomposed by potassium, the metal seizing upon the oxygen and Carbon being deposited. It is also decomposed under similar circumstances by being passed through an ignited tube together with hydrogen Gas. Carbonic Oxide consists of half a volume of oxygen + one volume of gaseous Carbon condensed into one volume; or one atom of oxygen + one atom of Carbon.

#### Subsect. 2.—Carbonic Acid.

(312.) A. Carbonic Acid was discovered by Dr. Black in 1757. He obtained it from common limestone or magnesia, and gave to it the name of *Fixed Air*. (u.) He recognised also its formation during combustion, fermentation, and respiration. Carbonic Acid exists in small proportion in the atmosphere, and has been found by Saussure on the summit of Mont Blanc; also by Humboldt, in air collected by Garnerin in a balloon at the height of several thousand feet above the surface of the Earth. Vogel, however, states that a portion of air collected at sea, only two leagues from the shore at Dieppe, contained a quantity so small as to be almost inappreciable. (v.) Mr. Dalton estimates the quantity existing in atmospheric air at about one thousandth of the volume. Saussure, jun., on experiments made near Geneva, at 4.79 parts in 10,000, in the month of January, and at 7.15 parts on an average in the same quantity, in the months of July and August.

In old wells and similar places it is frequently generated in such quantities as to be fatal to any animal that enters such an atmosphere; it is then commonly called *Choke Damp*. It exists naturally in a curious though small cavern by the side of the Lago d'Agnano, in Italy; a district entirely volcanic; where it is mixed with sulphurous exhalations. Many mineral waters contain it in considerable quantities; such are those of Tunbridge, Carlsbad, Seltze, Pyrmont, and many others. United with lime and magnesia it forms some of the most extensive rocks of which this Earth consists. It is this substance which gives the agreeable briskness to beer, cider, champagne wines, and other fermented liquors.

Part II

(313.) B. Carbonic Acid is readily procured by putting a few small lumps of marble or chalk into a Gas bottle, and pouring upon them either sulphuric Acid diluted with six times its weight of water, or muriatic Acid, which is still better, and may be rather more diluted. The Gas disengaged may be received in jars over the mercurial trough, or even over water, though in this case some is absorbed by that Fluid. The composition of this Gas is best shown by exhibiting both its synthesis and analysis. By the combustion of a known weight of charcoal or of diamond in oxygen Gas, a quantity of Carbonic Acid Gas is generated, which may be weighed or otherwise estimated; and hence the quantity of oxygen taken into combination may be ascertained.

On the other hand, its analysis may be effected by various methods.

1. By passing a succession of electric discharges through a quantity of Carbonic Acid Gas confined over mercury, Dr. Henry found that it was decomposed into Carbonic oxide and oxygen; and when all excess of Carbonic Acid is removed, the remaining mixed Gases may be again united by the electric spark, so as to reproduce Carbonic Acid. (w.)

2. By heating potassium in Carbonic Acid Gas, Davy found that the metal took to itself oxygen, and that Carbon was deposited.

3. By heating phosphorus in Carbonic Acid Gas, no decomposition is produced; but Mr. Tennant found that if the vapour of phosphorus were passed over small fragments of Carbonate of lime made red-hot in a coated tube of glass, decomposition takes place; phosphoric Acid is formed, and Carbon is found as a black powder mixed with the marble. (x.)

From these and such processes it is ascertained that Carbonic Acid consists of two atoms of oxygen + one atom of Carbon: or, according to Gay Lussac's views, of one volume of Gaseous Carbon + one volume of oxygen, condensed into one volume.

(314.) C. Gaseous Carbonic Acid has the following properties. It instantly extinguishes flame, and is quite fatal to animal life. It is heavier than common air; having a Specific Gravity of 1.52778. It is absorbed by water, and the quantity so taken up is in proportion to the pressure employed. From such water it is again expelled by boiling, by the exhaustion of an air-pump, or by the freezing of the water. When moisture is present, it reddens vegetable blue colours. It is highly antiseptic, preventing the putrefaction of animal substances immersed in it.

Carbonic Acid has been exhibited in a liquid state by Mr. Faraday. This excellent Chemist procured it in this form by disengaging it from Carbonate of ammonia, under the violent compression of a sealed tube, one end of which was placed in a freezing mixture. The Liquid was a colourless Fluid, floating upon sulphuric Acid and water contained in the tube. It distils rapidly over at a temperature below 32° Fahrenheit. Its refractive power is much below that of water. The pressure under which this Fluid formed was found to be thirty-two atmospheres.

The action of the other elementary bodies upon Carbonic Acid has been but little examined, so that we here pass on to the principal purpose for which it is prepared. Soda water, as it is called, consists of water strongly impregnated with this Gas, and is both formed and preserved under considerable pressure, which is never removed until the bottles are opened for

**Chemistry** use. It is obtained from the action of sulphuric Acid upon chalk; and sometimes a small quantity of alkali has been dissolved in the water to render it more tenacious of the Gas which it absorbs.

*Compounds of Carbon and Hydrogen.*

So numerous and varied are the compounds of Carbon and Hydrogen, which have been obtained by Chemical processes, that some Chemists have been led to suppose that these two elements are capable of uniting in almost an indefinite variety of proportions. It is, however, much more probable, that these Gases are, in fact, only admixtures containing different quantities, of two or three well-defined combinations. There is also this peculiarity in the compounds which we are about to notice; that Gases differing in properties are produced by the very same proportionate combination of the two constituent elements. The only appreciable difference in their constitution is, however, one which we might readily suppose would produce a very marked effect upon the combination formed; viz. that the degree of condensation undergone by the Gaseous elements in one case, may be double or triple of that which they suffer in another case, though a Gas be still the result. Thus, if the views of Mr. Dalton be correct, one atom of Carbon + one atom of Hydrogen produces olefiant Gas; and three atoms of Carbon + three atoms of Hydrogen produce superolefiant Gas; both the compounds presenting only one volume of resulting Gas.

We shall here notice in succession, the various described compounds of Carbon and Hydrogen, though our information concerning them is at present far from being full and satisfactory; some resting on much stronger evidence than others. They are as follows:

	Atoms or vols. of Carbon.	Atoms or vols. of Hydrogen.	Forming.
Light Carburetted Hydrogen . . . . .	1	+	2 1 volume.
Olefiant Gas . . . . .	2	+	2 1 volume.
Superolefiant Gas (Oil Gas &c) . . . . .	3	+	3 1 volume.
Bicarburet of Hydrogen . . . . .	6	+	3 Liquid.
A Liquid not named (Faraday) . . . . .	4	+	4 Liquid.
Nafta of Coal Tar . . . . .	6	+	6 Liquid.
Naftaline . . . . .	12	+	1 Solid.

**Subject 3.—Light Carburetted Hydrogen.** (*Heavy Inflammable Air: Inflammable Air of Marshes: Hydro-carburet: Proto-carburet of Hydrogen: Bi-hydro-guret of Carbon, of Thomson.*)

(315.) Mr. Dalton was the first to examine this Gas with care, though it was known to Priestley and Cruickshanks. It may be obtained by disturbing the mud at the bottom of any stagnant pond, from which it rises in bubbles through the water, and is to be collected in a jar or bottle as usual. Thus obtained it contains about five per cent. of carbonic Acid, and rather less nitrogen. It may also be obtained from coal Gas, of which it forms a part, by removing other Gaseous products with which it is mixed.

This Gas has neither scent nor taste; it extinguishes burning bodies, and is itself combustible, burning with a bright yellow flame. It is not decomposed by being passed through moderately heated tubes. Chlorine aided by light decomposes this Gas, if moisture be present: the Hydrogen unites with the chlorine to form muriatic Acid; and the oxygen and carbon pro-

duce carbonic Acid or carbonic oxide, according to the proportions employed. By exposing the mixed Gases to electricity or to a red heat, hydrochloric Acid is formed and carbon deposited. (y.)

(316.) From the researches of Dr. Henry, it was first clearly ascertained that the *Fire Damp* of coal mines is chiefly this Gas. Its formation takes place spontaneously in the beds of coal; it then collects in cavities, and becoming mixed with atmospheric air, it forms that highly explosive compound, which lights by the approach of a candle and causes frequent melancholy accidents in mines.

The researches made by Sir H. Davy, and the result of them, must be considered as among the most striking and beneficial applications of Chemical Science to the purposes of life. He first ascertained that when the inflammable Gas is mixed with three or four times its volume of air it is not explosive. When mixed with five or six times its volume it detonates feebly; but powerfully when the proportion is one to seven or eight: it ceases to be explosive when more than fourteen times the volume of common air is mixed with it.

With regard to the temperature at which the mixed Gases will unite, it was found that iron at even white heat was insufficient, but that any flame, however small, would cause the Gases to explode.

It had been shown by Professor Tennant, in his Lectures at Cambridge in 1814, that flame would not traverse tubes of small diameter: (z.) but there is no evidence to prove that Sir H. Davy's researches were directed by a knowledge of this fact, though it is not improbable that he was acquainted with it. However, proceeding in his experiments, he found that not only extremely short tubes but even a net of wire gauze was sufficient to interrupt the course of flame: and he made the admirable application of this principle to the construction of the *Safety Lamp*. This instrument consists of a lamp of the common construction, but entirely surrounded with a cage of wire gauze. When the miner, guided by this lamp, arrives in mixed air of such quality as to be explosive, the flame of the wick at first enlarges, and should the Gas within the lamp take fire, it extinguishes the flame of the lamp and the miner must withdraw: for although no flame passes through the apertures of the gauze to ignite the Gas of the mine, yet in a short time the iron net may be destroyed by the intense heat within. Some lamps have been made with a sort of cage of platinum wire hanging over the wick. The effect of this is, that should an explosion take place within the lamp, so as to extinguish it, the platinum wire becomes sufficiently heated to continue to glow at a red heat by the silent combination that is being produced between the Gases of the explosive compound, and thus to afford the miner a feeble light for his escape. (aa.)

This sort of action may be elegantly exhibited by twisting a few coils of platinum wire round the wick of a spirit-lamp, so that the five or six last turns of the wire stand about one-fifth of an inch above the wick. The lamp is thus lighted, and when the wire is red-hot, may be suddenly extinguished. The platinum will continue to glow for many hours in consequence of the slow combustion which it produces between the vapour of the spirit and the atmospheric air. (bb.)

This Gas consists of carbon one atom + Hydrogen two atoms.

Chemistry. *Subject. 4.—Olefiant Gas. (Bicarburetted Hydrogen: Per-carburetted Hydrogen: Hydroguret of Carbon, Thomson.)*

*Olefiant Gas.* (317.) The discovery of this Gas was made by the associated Dutch Chemists in 1796. They named it Olefiant Gas, from its property of forming an oil-like substance with chlorine.

To obtain it, let three measures of strong sulphuric Acid be distilled with one measure of alcohol in a glass retort by a very gentle heat. The Gas may be collected over water and freed from carbonic Acid by a solution of caustic potassa.

Olefiant Gas has a slight odour of sulphuric ether, which is formed during its production. It burns with a flame much more luminous than that of light carburetted hydrogen, and it detonates violently when mixed with oxygen in Volta's eudiometer.

When equal quantities of Olefiant Gas and chlorine are mixed together, the volume immediately diminishes and a substance is formed resembling oil in its appearance, but being more like an ether in its properties. To obtain it quite pure, it should be washed with water, and then distilled over from dry chloride of calcium. This liquid boils at 152° Fahrenheit. Its Specific Gravity at 45° Fahrenheit = 1.2201. It consists of equal volumes of the two elements, chlorine and Olefiant Gas, or of two atoms of the latter to one atom of the former. Dr. Henry proposes to call it Hydro-chloride of Carbon, which seems a very appropriate name. (cc.)

A compound somewhat analogous, formed of iodine and Olefiant Gas, is described by Mr. Faraday. (dd.) Another combination of the same substances was discovered by M. Serullas. (ee.)

*Subject. 5.—Superolefiant Gas. (Dalton.)*

(318.) Under such respectable authority as that of Mr. Dalton and Dr. Henry, we cannot omit to mention a Gas discovered and so named by the former Chemist. We are very sensible that these compounds of carbon and hydrogen are by no means fully understood; and therefore there is the greater need to call the attention of Chemists to the point.

Mr. Dalton adduces very strong evidence of the presence of this Gas among the various products obtained by the distillation of oil and coal; but he has not as yet exhibited it in a separate form. Dr. Henry states that it must be a permanent Gas at our temperatures, and not a vapour, for he was unable to condense it by artificial cold. He considers it as composed of three volumes of the vapour of carbon and three volumes of hydrogen condensed into one volume. (ff.)

*Subject. 6.—Bicarburet of Hydrogen. (Faraday.)*

(319.) There is an instrument called Gordon's portable Gas lamp, consisting of a cylindrical copper vessel, into which oil Gas is forced and compressed with a power equivalent to thirty atmospheres. During the process of compression a considerable quantity of Fluid is condensed, and remains a Liquid at the ordinary atmospheric pressure. As thus obtained it boils at 60° Fahrenheit; but the temperature gradually rises, and the whole is not dissipated under a temperature of 250° Fahrenheit. In consequence of the boiling point appearing more steady between 176° and 190°, Mr.

Faraday carefully examined the Fluid which came over at that temperature. By various precautions he thus obtained the Fluid which he calls the Bicarburet of Hydrogen. Part II.

It is a colourless transparent Liquid, having a Specific Gravity of 0.85 at 60° Fahrenheit. It congeals at 32° Fahrenheit, and boils at 186°. It is slightly soluble in water, but readily so in fixed and volatile oils, ether, or alcohol. It burns with a bright yellow flame. Potassium does not obtain any oxygen from it. It is decomposed by passing its vapour through a red-hot porcelain tube, by which carbon is deposited and Carburetted Hydrogen escapes. According to Mr. Faraday's Analysis its constitution is six atoms of carbon + three atoms of Hydrogen.

*Subject. 7. ————— (Faraday.) Quadro-carburetted Hydrogen of Thomson.*

(320.) Another combination also of carbon and hydrogen was recognised by Mr. Faraday, but he did not propose a name for it. It is obtained by heating in the hand the condensed Liquid obtained from oil Gas, and suffering the vapour thus raised to pass through tubes cooled down to zero Fahrenheit. A Liquid is thus condensed which boils upon a very slight elevation of temperature; and before the thermometer rises to 32° Fahrenheit it is wholly reconverted into vapour.

This vapour burns with a brilliant flame. At 60° Fahrenheit and bar. 29.94 it has a Specific Gravity of about 1.9065. The Specific Gravity of the Liquid is 0.627; so that it is the lightest substance known among Liquids or Solids.

It appears that this substance consists of four atoms of carbon + four atoms of Hydrogen; and that in its state of vapour eight volumes of its constituents in the Gaseous state are condensed into one volume.

*Subject. 8.—Nafta from Coal Tar.*

(321.) During the distillation of Coal Tar, this volatile Liquid is condensed, and has received its name from its similarity to mineral Nafta. It is highly inflammable and has a strong empyreumatic odour. Dr. Thomson says that the vapour of this Liquid "requires nine times its volume of oxygen Gas to condense it completely; and when one volume of it is consumed in this way, there remain behind six volumes of Carbonic Acid Gas as a residue." He states, also, that "his vapour" is not condensed by passing it through water." Thus it consists of six atoms = six volumes of carbon vapour + six atoms = six volumes of hydrogen, condensed into one volume of vapour. (gg.)

*Subject. 9.—Naphthaline.*

(322.) The substance to which this name has been given was first brought into notice by Mr. Gordon in 1820. (hh.) It also is obtained from the nafta of coal tar by very gentle distillation. The nafta, at first passes over in consequence of its greater volatility, and the Naphthaline afterwards rises in vapour and condenses upon the neck of the retort, in the form of a white crystalline Solid. Crystallized Naphthaline is rather heavier than water, has a slight and not unpleasant odour, and a nacreous appearance. It fuses at 180° Fahrenheit, and boils at 410° Fahrenheit. Naphthaline

**Chemistry.** is not readily inflamed, but when once set on fire it burns freely with much smoke. It is little soluble in either cold or hot water, but readily so in alcohol, ether, olive oil, or turpentine. The alkalis do not affect it, but acetic and oxalic Acids dissolve it, and form pink-coloured solutions. Sulphuric Acid combines with it to form a new compound Acid which Mr. Faraday has called the Sulpho-Naphthalic Acid. (ii.) Dr. Thomson analyzed Naphthaline, and supposes it to consist of an atom and a half of carbon and one atom of hydrogen. The properties of this substance have been chiefly made known, by a very able *Memoir* on the subject by Professor Kidd of Oxford. (kk.) We have in this subsection adhered to the spelling made use of by Dr. Kidd, but usually we have followed the spelling of *Nafta*, proposed by the late anti-fable and distinguished traveller Dr. E. D. Clarke. Consult also ref. (il.) and the very important remarks of Professor Thomson in his *First Principles*, vol. i. p. 150: but it must be acknowledged that the whole of this subject requires further investigation.

## Gas Light.

(323.) The honour of having first introduced the carburets of hydrogen for common purposes of illumination seems due to Mr. Murdoch. The Gas is obtained by heating coal or oil in iron retorts; and, if necessary, the Gas evolved undergoes various processes of purification before it arrives at the large gasometer, in which it is kept for the supply of the numerous and distant burners wherein it is consumed. All statements tend to show, that the Gas thus evolved consists of a mixture of the several carburets of hydrogen, and that in very variable proportions. As first produced, there is also carbonic Acid, hydrogen, sulphuretted hydrogen, and some nitrogen; all which are injurious to the ultimate purpose of the manufacture. It appears quite certain, the goodness of Gas varies directly in proportion to the quantity of those Gases present, which contain the largest proportion of carbon in their constitution. Thus, olefiant Gas, superolefiant Gas, and the vapours of naphthaline, are far more serviceable for illumination than the light carburet of hydrogen.

The Gas from common coal is least expensive, but it requires more trouble for its purification, and is by no means so luminous as the Gas from oil. The Gas from coal is still better, in consequence of the larger proportion of bituminous matter which it contains. But oil Gas is the best of all; it gives a brighter light, and does not require so extensive an apparatus for its production.

Mr. Brande made some experiments on the respective illuminating powers of different Gases, and concluded, that to produce a light equal to that of ten wax candles for one hour, there were required

2600	cubic inches of olefiant Gas.
4875	..... oil Gas.
13120	..... coal Gas.

It is, however, more near the truth to consider oil Gas as about equal in power to twice its volume of coal Gas. The following is an estimate of comparative expense by the late Mr. Creighton of Glasgow.

Valuing the quantity of light given by 1 lb. of tallow candles at ..... 1s. 0d.

An equal quantity of light from sperm oil, consumed in an Argand lamp, will cost.....	0 6
Ditto from whale oil Gas.....	0 4
Ditto from coal Gas.....	0 2

Part II

For further particulars on this subject, consult reference (nn.), but especially the Papers of Dr. Henry, and the very able Essay by Drs. Turner and Christison.

## References to § 3.

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## § 4.—Borax. (Bore, Thenard; Boracium, Davy.)

(324.) A. "The saline substance called Borax has long been familiar to European artists, being employed to facilitate the fusion of the precious metals, and in the formation of artificial imitations of the precious stones. It comes from the East Indies, and is said to be found chiefly in certain lakes in Thibet and China. The word Borax occurs first in the writings of Geber, an Arabian Chemist of the Xth century. In the year 1702, Homberg, by distilling a mixture of Borax and green vitriol, obtained a peculiar substance in small white shining plates, which he called *sedative*, or *nar-*

**Chemistry.** cotic salt, and which was considered as an efficacious remedy in continued fevers. (a.) Lemery the younger, in the year 1727, found that this substance could be separated from Borax by the mineral Acids. (b.) In 1731, Geoffroy ascertained that sedative Salt gave a green colour to the flame of alcohol; and that Borax contains in it the same alkaline substance that constitutes the basis of common salt. (c.) In 1752, Baron demonstrated by satisfactory experiments that borax is composed of sedative salt and soda. (d.) Sedative salt was found to possess the properties of an Acid; it was therefore called *Boracic Acid*: but the composition of this Acid remained altogether unknown. Crell, indeed, published a set of experiments on it in the year 1800, in which he endeavoured to show, that its basis was a substance very similar to charcoal in its properties. (e.) But when his experiments were repeated by Sir H. Davy they did not succeed. Davy, in the year 1807, exposed a quantity of Boracic Acid to the action of the Galvanic Battery, and observed that a black matter was deposited upon the negative wire, which he considered as the basis of this Acid, but he did not prosecute the discovery further at that time. In the summer of 1808, MM. Gay Lussac and Thenard succeeded in decomposing this Acid by heating it in a copper tube with potassium. They examined the properties of its base, to which the name of *Boron* has been given, and published a detailed account of these properties. (f.) Davy, in 1809, decomposed the Acid by the process of the French Chemists, and published likewise an account of the properties of Boron." (g.)

(325.) B. "Boron may be obtained by the following process. One part of pure Boracic Acid, previously melted and reduced to powder, is to be mixed with two parts of potassium, and the mixture put into a copper or iron tube, and gradually heated till it is slightly red, and kept in that state for some minutes. At the temperature of 300° the decomposition begins, and the mixture becomes intensely red-hot, as may be perceived by making the experiment in a glass tube. When the tube is cold, the matter in it is to be washed out with water, the potash formed is to be neutralized with muriatic Acid, and the whole thrown upon a filtre. The Boron remains upon the filtre, and may be washed and dried in a moderate heat." (h.) Dr. Thomson, however, recommends avoiding the use of a filtre by washing the Boron in a glass vessel, repeatedly drawing off the liquid with a syphon after the Boron has been allowed to subside.

(326.) C. Boron has neither scent nor flavour; its colour is an olive brown; it is not soluble in water, ether, alcohol, or oil, even assisted by heat; it is infusible, and in close vessels remains unchanged. When first prepared it does not sink in sulphuric Acid of Specific Gravity 1.844: but after having been strongly heated it sinks rapidly through that Fluid. It is a non-conductor of Electricity. Heated in water to 176° Fahrenheit it does not decompose that Fluid.

(327.) D. At ordinary temperatures: it does not undergo any change in atmospheric air or oxygen Gas; but at a temperature below 600° Fahrenheit it undergoes a rapid and vivid combustion. The process, however, is not altogether complete, for as Boracic Acid, the product of this combustion, is fusible, each globule of Boron becomes coated with the vitrified Acid, and a nucleus of the base remains unoxidized. For Boracic Acid, See subsect. 1.

(328.) E. According to Davy, when Boron is heated in chlorine Gas, the substances unite, evolving a brilliant white flame; a white sublimate condenses on the sides of the vessel in which the experiment is made, and the Boron receives a white coating, which on being washed off proved to be Boracic Acid. (g. p. 41.) On the other hand, Gay Lussac and Thenard state that Boron is not sensibly affected by dry chlorine Gas. (i.)

(329.) F. With fluorine Boron unites to form a powerful Acid, the Boro-fluoric already noticed. (194.)

(330.) G. Unexamined.

(331.) H. Sir H. Davy could not unite Boron to nitrogen, (g. p. 42.) nor was he more successful in his attempts upon hydrogen. Gmelin, however, effected this in the following manner. He exposed a mixture of four parts of iron filings, with one part of Boracic Acid, to a full red heat for half an hour in a crucible. The fused mass dissolved with effervescence in dilute muriatic Acid and boruretted hydrogen Gas was evolved. The Gas had the smell of common hydrogen Gas from iron, mixed with a slight smell of garlic. It burned with a reddish yellow flame, surrounded by a green border: some white fumes appearing in the vessel in which the combustion took place. (k.) As yet the union of Boron with carbon has not been effected.

(332.) I. Boron has been united to iron and platinum by Descotils, who heated charcoal, boracic Acid, and the metallic filings made into a paste with oil in a crucible. The compound preserved a metallic appearance. (l.) Gmelin made similar experiments. (m.) Davy found that with potassium it formed a grey metallic-looking compound. But with many other metals it seems to refuse to combine.

(333.) K. Boron decomposes nitric Acid with rapidity, nitrous Gas being evolved, and the Boron becoming boracic Acid. It also decomposes the sulphuric Acid, when aided by heat; and at a high temperature it takes oxygen from a number of the compound Salts, nitrates, sulphates, and carbonates. It reduces also several of the metallic oxides.

(334.) L. M. On these heads we have nothing to remark.

#### Subsect. 1.—*Boracic Acid.*

(335.) A. We have already seen (324.) that Boracic Acid was obtained in 1702 by Homberg from the decomposition of Borax, in which Salt it is found naturally combined with soda. Boracic Acid is found combined with magnesia in the mineral called Boracite found in the Kaikberg, near Lunenburg, also in the Tincal before mentioned, and in several thermal lakes in Tuscany.

(336.) B. Boracic Acid is most readily obtained by dissolving Borax in hot water, gradually adding sulphuric Acid to the filtered solution, until the Liquid becomes rather acid. A number of small shining laminary crystals gradually form and subside as the liquor cools. These are crystals of Boracic Acid, which must be well washed with clean water, and then dried between folds of blotting paper. In this state it is a hydrate: the water may be driven off by fusion, and the Boracic Acid remains pure.

(337.) C. This hydrate exhibits thin hexagonal scales with a pearly lustre, has something the appearance and feel of spermaceti: its Specific Gravity is .479, but the pure Acid after fusion is 1.803. Boracic

**Chemistry.** Acid has no smell, but by affusion of a little Sulphuric Acid a musky odour is developed. Boracic Acid is not volatile, but after fusion, at a red heat, it becomes on cooling a hard transparent glass, which becomes opaque externally by exposure to the air, but does not deliquesce. It has the property of reddening vegetable blues.

(338.) D. E. F. G. None yet recognised.

(339.) H. Neither have these substances any action upon Boracic Acid; but it is soluble in alcohol, and by the aid of considerable heat in oils also.

(340.) I. Of the metals, potassium and sodium alone have been found capable of decomposing Boracic Acid. With regard to the action of its solution upon metals, it dissolves iron, zinc, and perhaps copper.

(341.) K. Boracic Acid combines with the oxides of every class of metals to form Salts, which are called Borates.

(342.) L. The presence of Boracic Acid is most easily recognised by its property of colouring the flame of burning bodies green. This is easily exhibited by the combustion of alcohol holding it in solution; but the neatest method, when the quantity is small, is to dip a cotton thread into a Boracic solution, and then, after drying the thread, to set fire to it.

(343.) M. Boracic Acid is used in the fabrication of pastes for the imitation of precious stones; and in the analysis of minerals, which naturally contain the fixed alkalis. Borax, the Borate of soda, is employed in soldering to clean the metallic surfaces, and by its fusion to prevent oxidation, and thus to facilitate the union of the metallic surfaces.

#### References to § 4.

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#### § 5.—Phosphorus.

(344.) A. Phosphorus "was accidentally discovered by Brändt, a Chemist of Hamburgh, in the year 1669, (a.) as he was attempting to extract from human urine a Liquid capable of converting silver into gold. He showed a specimen of it to Kunkel, a German Chemist of considerable eminence, who mentioned the fact as a piece of news to one Kraft, a friend of his at Dresden. Kraft immediately repaired to Hamburgh, and purchased the secret from Brandt for 200 dollars, exacting from him, at the same time, a promise not to reveal it to any other person. Soon after he exhibited his Phosphorus publicly in Britain and France, expecting doubtless that it would make his fortune. Kunkel, who had mentioned to Kraft his intention of getting possession of the process, being vexed at the treacherous conduct of his friend, attempted to discover it himself; and about the year 1674 he succeeded, though he only knew from Brandt that urine was the substance from which Phosphorus had been procured. (b.) Accord-

ingly he is always reckoned, and deservedly too, as one of the discoverers of Phosphorus."

"Boyle likewise discovered Phosphorus. Leibnitz, indeed, affirms that Kraft taught Boyle the whole process, and Kraft declared the same thing to Stahl. But surely the assertion of a dealer in secrets, and one who had deceived his own friend, on which the whole of this story is founded, cannot be put in competition with the affirmation of a man like Boyle, who was not only one of the greatest Philosophers, but likewise one of the most virtuous men of his Age; and he positively assures us that he made the discovery without being previously acquainted with the process." (c.) "Mr. Boyle revealed the process to his assistant, Godfrey Hankwitz, a London apothecary, who continued for many years to supply all Europe with phosphorus. Hence it was known to Chemists by the name of English Phosphorus. (d.) Other Chemists, indeed, had attempted to produce it but without success, (e.) till in 1737, a stranger appeared in Paris, and offered to make Phosphorus. The French Government granted him a reward for communicating his process. Heliot, Dufay, Geoffroy, and Duhamel saw him execute it with success; and Heliot published a very full account of it in the *Memoirs of the French Academy for 1737.*" (f.) Thomson, *Syst.*

"The process for obtaining Phosphorus was further improved by Margraf. (g.) Gahn first detected its presence in bones; and Scheele devised a method for obtaining it from that source.

In its pure state Phosphorus is not known to exist in nature, but its combinations are found in many animal substances, and also in some minerals.

(345.) Phosphorus is now usually obtained by calcining bones; the solid residuary matter consists for the most part of phosphate of lime. This white substance is pulverized and digested for several hours with half its weight of concentrated sulphuric Acid: but to this water is added, sufficient to reduce the mass to the consistency of cream. By this process the phosphate of lime is decomposed; sulphate and biphosphate of lime result. The latter Salt is dissolved out by boiling water, then evaporated to the consistency of sirup, mixed with one fourth its weight of powdered charcoal, and submitted to a good heat in an earthen retort. The beak of the retort should terminate in cold water; the Phosphorus is condensed by the water, and falls down in drops. Phosphorus is further purified by fusing it in hot water, and carefully pressing it through chamois leather; or else by a subsequent gentle distillation.

(346.) C. Phosphorus is generally seen of a light brown colour, but when quite pure it is nearly colourless, with a waxy appearance and fracture. It fuses at about 108° Fahrenheit, and rises fully in vapour at 550° Fahrenheit, but at 219° Fahrenheit *in vacuo*.

It may be readily cut with a knife, and has a Specific Gravity about 1.77.

(347.) D. The affinity of Phosphorus for oxygen is very considerable, and most energetic combinations take place between these substances. In atmospheric air Phosphorus undergoes a slow combustion even when no extraordinary heat has been applied, and to this cause must be attributed the luminous appearance which it exhibits in the dark. A very slight elevation of temperature, even that produced by gentle friction, is sufficient to throw it into a state of vivid comb-

Chemistry. bustion, during which intense light and heat are developed.

The following is a more specific summary of the mutual action of Phosphorus and oxygen given from M. Thenard, who cites the experiments of M. Bellani de Monaz. (*h.*)

1. Phosphorus placed in pure oxygen at an ordinary atmospheric pressure and temperature undergoes no change; but by diminishing the pressure, combination takes place, the Gas is absorbed, and hypophosphoric Acid is formed. And, generally, the more the pressure is diminished, the lower is the temperature at which the substances unite; but that no combination takes place below 41° Fahrenheit.

2. Further that if greater pressures are employed, a greater elevation of temperature is required to produce combination.

3. The addition of a greater or less quantity of azote or hydrogen, or carbonic Acid to a given volume of oxygen, produces with reference to the combustion of Phosphorus therein below 80° Fahrenheit, the same effects as diminution of pressure. Hence the luminous appearance of Phosphorus in atmospheric air; it burns slowly, absorbing the oxygen and leaving the azote.

4. Phosphorus ought to pass into the state of vapour at ordinary temperatures by its own elastic force, in any Gas that does not act upon it Chemically. Hence if Phosphorus be allowed to vapourize in oxygen Gas, and then hydrogen, or azote, be admitted to this Gas, a luminous cloud is seen; or if, on the contrary, its vapour be formed in hydrogen, or azote, or carbonic Acid, and oxygen be admitted to this, the same effect is produced.

Whether any combination between oxygen and Phosphorus exist in such proportions as to form oxides, is a point not fully ascertained; but it is generally admitted that there are three such combinations by which distinct Acids are formed. These are the Phosphoric Acid, subsect. 1; the Phosphorous Acid, subsect. 2; and the Hypophosphorous Acid, which we shall be able here briefly to describe.

(348.) The *Hypophosphorous Acid* was discovered by M. Dulong, in 1816. Phosphuret of baryta is put into water. Phosphate of baryta is formed, and being insoluble is precipitated; to the clear filtered liquor just enough sulphuric Acid is added to remove the baryta; and the remaining solution produces, by evaporation, a viscid uncrystallizable solution of the Hypophosphorous Acid. By increased heat this Acid undergoes decomposition. (*z.*) The Salts formed by this Acid are remarkable for being all soluble and highly deliquescent. The Acid itself is supposed to contain one atom of oxygen + two atoms of Phosphorus, but with regard to the comparative proportion of the elements of all the compounds of oxygen and Phosphorus, there still seems a little uncertainty. By some this Acid has been even supposed to be an hydracid, that is to say, to contain hydrogen as a constituent element.

(349.) E. Chlorine combines with Phosphorus in two proportions. The *Protochloride of Phosphorus* (or Chloride) is best prepared by passing the vapour of Phosphorus over corrosive sublimate heated in a glass tube. Thus protochloride of mercury (calomel) is formed and the Phosphorus unites with the remaining atom of chlorine which is set free. This protochloride is a Liquid whose Specific Gravity is 1.45. It is a

neutral substance not affecting vegetable colours, and contains one atom of each of its constituents.

(350.) *Deutochloride of Phosphorus* (Bichloride of some authors) is formed by placing Phosphorus in chlorine Gas; spontaneous combustion takes place, and a white solid substance forms on the sides of the retort. This substance is volatile at a temperature below 212° Fahrenheit. It acts violently on water; hydrochloric Acid and Phosphoric Acid being the results. When transmitted through a red-hot porcelain tube with oxygen Gas, the chlorine is set at liberty and Phosphoric Acid is produced, showing that at high temperatures the affinity of oxygen for Phosphorus is superior to that of chlorine for the same substance. This Deutochloride contains two atoms of chlorine + one atom of Phosphorus.

(351.) F. unexamined.

(352.) G. Iodine combines with Phosphorus at ordinary atmospheric temperatures; heat is evolved, and, as it appears from Dr. Traill's experiments, there is or is not light according to the mode in which the experiment is conducted. Two compounds are supposed to exist, but do not seem to be very tenacious of a definite state of combination. (*k.*)

(353.) H. Phosphorus combines with hydrogen in two proportions. The resulting substances are both Gaseous, and some little difficulty may occur to the student from the varied nomenclature employed by Chemists in speaking of these compounds. We shall adhere to the general rules proposed in (110.) and (111.) The *Prot-hydroguret of Phosphorus* (Phosphuretted Hydrogen of Gengembre and Kirwan; Hydroguret of Thomson) was discovered in 1783 by Gengembre, (*l.*) and independently, in 1786, by Kirwan; (*m.*) it has been further examined by Raymond, (*n.*) Dalton, (*o.*) and Thomson. (*p.*) It may be obtained by heating Phosphorus in a solution of pure potassa; or by heating a paste formed of small fragments of Phosphorus, newly slaked lime, and a little water; or by filling a small retort with water acidulated with muriatic Acid, and then adding to it a few lumps of phosphuret of lime; a very gentle heat is to be applied, and the Gas evolved must be received over water.

The Prot-hydroguret of Phosphorus has a peculiar and disagreeable odour. It is slightly soluble in water; inflames spontaneously, and burns with splendour when it comes in contact with atmospheric air or oxygen Gas. It is decomposed by a strong heat, or by the electric spark. It consists, as the name indicates, of one atom of each of its elements.

(354.) The *Deut-hydroguret of Phosphorus* (Bi-hydroguret of Thomson) was discovered by Davy in 1812. He procured it by heating crystallized Phosphorous Acid. The prot-hydroguret is also reduced to this state by exposure to the sun, one proportion of its Phosphorus being deposited. This Gas has a scent similar to that of the prot-hydroguret, but less strong; it does not inflame spontaneously by contact with common air or oxygen Gas, but burns with a white flame in chlorine. This Gas contains two atoms of hydrogen + one atom of Phosphorus. These two compounds might also be called sub-phosphuret and Phosphuret of hydrogen.

(355.) Phosphorus unites with carbon. This Phosphuret was first formed by Proust. Thomson gives the following as the readiest method for obtaining it:



**Chemistry.** "Allow Phosphuret of lime to remain in water till it has given out all the Phosphuretted Hydrogen Gas that it is capable of evolving. Then add to the Liquid a considerable excess of muriatic Acid, agitate for a few moments, and throw the whole upon a filter. Phosphuret of carbon will remain upon the filter. Let it be properly washed and dried."

"Phosphuret of carbon is a soft powder of a dirty lemon yellow colour, without either taste or smell. When left in the open air it very slowly imbibes moisture, emits the smell of carburetted hydrogen, and acquires an acid taste. Hence it decomposes the water which it absorbs, and its Phosphorus is slowly converted into Phosphoric Acid. It does not melt when heated, nor is it altered when kept in a temperature higher than that of boiling water. It burns below a red heat, and when heated to redness gradually gives out its Phosphorus. The charcoal remains behind in the state of a black matter, being prevented from burning by a coating of Phosphoric Acid with which it is covered. When the powder is thrown over the fire in small quantities, it burns in beautiful flakes. It is composed of one atom of Phosphorus + one atom of carbon. (q.)

(356.) Phosphorus combines readily with sulphur in several proportions. The Phosphuret of sulphur has a yellow colour, and possesses great tendency to crystalline structure. Its properties are not very interesting, but for those who may wish to be made acquainted with them in detail, references are given. (r.)

(357.) Phosphorus is soluble in nitrogen Gas, forming a Gaseous compound which has been little examined.

(358.) Alcohol, ether, and oils dissolve Phosphorus more or less, and these solutions when spread upon paper become luminous in the dark, especially in a warm atmosphere.

(359.) I. The metals are almost all capable of being united to Phosphorus.

(360.) K. Phosphorus in its pure state cannot, of course, perform the part of either an Acid or a base. The action which it possesses upon Acids and bases depends in general on its affinity for oxygen; thus it decomposes the nitric Acid to obtain a portion of its oxygen, Gaseous oxide of azote being evolved. By a similar affinity it is capable of decomposing many, if not all, the metallic oxides.

(361.) L. In its elementary state Phosphorus is easily recognised by its luminous properties, and by its ready combustibility. Its properties when acidified will be considered hereafter.

(362.) M. The immediate uses of Phosphorus are very limited, but it has served to make a small portable instrument for obtaining a light. A small quantity of Phosphorus is fused with a little lime in the bottom of a bottle: in this process it undergoes a partial oxidation, so that when a common sulphur match is introduced and again removed into the air, it inflames. Phosphorus, when administered internally, proves one of the most powerful stimulants of the animal economy, thus forming a most powerful aphrodisiac.

#### Subsect 1.—Phosphoric Acid.

(363.) A. The discovery of Phosphorus led to the immediate formation of Phosphoric Acid, which is produced by its combustion; but its true nature could not have been understood previous to the theory of acidifi-

cation by oxygen. This Acid does not exist in a free state in nature, but when combined with lime it forms a principal ingredient in bones, and also a part of most animal matters.

(364.) B. Phosphoric Acid may be obtained quite pure by burning Phosphorus in oxygen Gas. White vapours are produced which condense in snowy crystals on the bottom of the retort. This solid anhydrous Acid attracts moisture from the air with great avidity, and soon becomes liquid. Phosphoric Acid may also be obtained by the action of Phosphorus on nitric Acid, but the experiment requires caution, as the decomposition takes place with violence. From Phosphoric Acid the water may be driven off by heat, and the pure Acid remains in a glassy state. Generally speaking, however, Phosphoric Acid is procured from bones by a process already adverted to. (337.) The biphosphate of lime is boiled for a few minutes with excess of carbonate of ammonia; thus carbonate of lime is precipitated, and a solution of phosphate and sulphate of ammonia remains. By evaporation, and finally by a strong heat in a platinum crucible, every thing except the Phosphoric Acid is driven off. This Acid is now for the most part supposed to consist of one atom of Phosphorus + two atoms of oxygen.

(365.) C. This Acid in its purest state is a white or transparent Solid, uniting readily with water in all proportions. M. Dulong considers that by heat alone it is impossible to expel all the water, and that what is called solid glacial Phosphoric Acid consists of three atoms of Phosphoric Acid + one atom of water. The taste is intensely sour, the effect in reddening litmus-paper is very energetic, and the Acid possesses high neutralizing powers upon the bases. This Acid is decomposed by the Voltaic pile.

(366.) D. None.

(367.) E. None.

(368.) F. Unknown.

(369.) G. Unexamined.

(370.) H. Nitrogen has no action on Phosphoric Acid. Carbon decomposes it at high temperatures.

(371.) I. Potassium and sodium decompose this Acid.

(372.) K. No other Acid is capable of employing the Phosphoric as a base; but with bases it forms numerous and important Salts. With single atoms of some bases it unites in several different proportions, forming sub-phosphites, phosphites, super-phosphites, and other classes of Salts, which we must not here enumerate. (t.)

(373.) L. The most marked reagent action of Phosphoric Acid is as follows. When exactly neutralized by carbonate of soda or potash, the solution undergoes no change of colour by passing a stream of sulphuretted hydrogen through it: acetate of lead produces a white precipitate, and nitrate of silver a yellow one. The former is dissolved by the addition of nitric or Phosphoric Acid, and the latter by ammonia, as well as by those Acids.

(374.) M. Phosphoric Acid is not generally employed in Medicine, but M. Lentin has recommended its exhibition in doses of twenty-five drops, to be taken in any diluent Liquid for phthisis.

#### Subsect 2.—Phosphorous Acid

(375.) The combustion of Phosphorus frequently produces both Phosphoric and Phosphorous Acid; but

**Chemistry.** the best process for obtaining the latter substance is to pass the vapour of Phosphorus through powdered corrosive sublimate in a glass tube. Chloride of Phosphorus is formed, and condenses in a liquid form. By putting this substance into water a decomposition takes place, the hydrogen and chlorine form hydrochloric Acid, and the oxygen unites to the Phosphorus to form Phosphorous Acid. The solution must then be evaporated, so as to drive off the hydrochloric Acid, and the remaining hydrous Phosphorous Acid will on cooling assume a crystalline structure. The spontaneous oxidation of Phosphorus in atmospheric air produces the same Acid.

With bases this Acid is capable of forming Salts, but they have not been examined much in detail. It appears, however, that there exist sub, neutral, and superphosphites. Consult the *Memoir* of M. Dulong. (u.)

#### References to § 5.

(a.) Homberg, *Mém. Ac. Par.* vol. x. p. 84. *Phil. Trans.* 1681. (b.) Kunkel, *Laborator. Chemicum*. p. 660. Weigleb, *Geschichte, &c. der Chemie*, vol. i. p. 41. (c.) Boyle, *Works*, ed. Shaw, vol. iii. p. 174. (d.) Hoffman, *Obs. Phys. Chem. Select.* p. 301. (e.) Stahl, *Fund. Chem.* vol. ii. p. 58. (f.) *Mém. Acad. Par.* 1737, p. 342. (g.) *Miscel. Berol.* 1740, vol. vi. p. 54. *Mém. Acad. Ber.* 1746, p. 84. Margraf, *Opusc.* vol. i. p. 30. (h.) *Bulletin de Pharmacie*, tom. v. p. 489. (i.) Dulong, *Phil. Mag.* vol. xlviii. p. 271. (k.) Davy, *Phil. Trans.* 1814, p. 79; and Gay Lussac, *An. de Chim.* vol. xci. p. 9. (l.) *Mém. des Sav. Etrang.* vol. x. p. 651. (m.) *Phil. Trans.* 1786, p. 118. (n.) *An. de Chim.* vol. x. p. 19; and vol. xxv. p. 225. (o.) *New Syst. Chem.* *Phil.* vol. ii. p. 457. (p.) *An. Phil.* vol. viii. p. 87. (q.) Thomson, *Syst.* vol. i. p. 277. (r.) Margraf, *Opusc.* vol. i. p. 11; Pelletier, *Jour. de Phys.* vol. xxxv. p. 382; Accum, *Nich. Jour.* vol. vi.; Briggs, *Nich. Jour.* vol. vii.; Pelletier *An. de Chim.* vol. iv. p. 10; Faraday, *Roy. Inst. Jour.* vol. iv. p. 361. (s.) Fourcroy, *An. de Chim.* vol. xxi. p. 199. (t.) Berzelius, *An. de Chim. et de Phys.* vol. ii. p. 151; vol. xi. p. 114; and Mitscherlich, vol. xix. p. 350. (u.) *Mém. d'Arcueil*, vol. iii. p. 420.

#### § 6.—Sulphur.

(376.) A. Sulphur is on the whole a plentiful substance, and has been known from the very earliest times. It occurs abundantly among the various products of volcanic fires, and is found also in certain mineral formations chiefly connected with clays and schists. Several of the metalliferous ores consist chiefly of this substance. When mixed with much earthy matter it is amorphous, but if its formation has taken place in cavities, or by slow processes, it presents very beautiful crystalline forms. The Island of Sicily produces it in great abundance.

(377.) B. Sulphur is obtained pure by gentle sublimation; it is then called *Flowers of Sulphur*, or *Flour of Sulphur*, but it is at first contaminated with a little sulphurous Acid, which must be removed by careful washing. Sulphur is at present considered a simple substance, though it has been difficult for some eminent Chemists to satisfy themselves that some hydrogen did not enter into its composition.

(378.) C. At our ordinary temperatures, Sulphur is a solid, brittle, and frequently crystalline substance. It

fuses at about 180° or 190° Fahrenheit, and is completely fluid at 220°. It rises in vapour slightly about 170°, but becomes Gaseous at 600° Fahrenheit. If melted Sulphur be poured into hot water it remains a tenacious waxy substance, and in this state is frequently employed to take impressions of gems, coins, &c. Sulphur is a nonconductor of electricity, and becomes negatively electric by friction. It possesses high refractive power upon light.

(379.) D. When heated in atmospheric air, or oxygen Gas, Sulphur takes fire, combining with the oxygen and forming Sulphurous Acid; but by various processes four distinct combinations between Sulphur and oxygen may be produced. These will be described in subsections 1, 2, 3, and 4.

(380.) E. Chloride of Sulphur is readily formed by passing a current of chlorine through Flowers of Sulphur, or by heating Sulphur in dry chlorine Gas. This substance was first described by Professor Thomson, (a.) and subsequently examined by A. Berthollet, (b.) and by Bucholz. (c.) Sir H. Davy discovered another combination between the same elements. (d.)

The *subchloride of Sulphur* formed by Thomson's process, is described by himself "a liquid of a brownish red colour, when seen by reflected light; but yellowish green when seen by transmitted light." Its smell is strong, and somewhat similar to that of sea plants. The eyes, when exposed to it, are filled with tears. The taste is acid, hot, and bitter, affecting the throat with painful tickling. It does not change the colour of dry litmus-paper; but if the paper be moist it immediately becomes red. Specific Gravity 1.6789 or 1.7. It readily dissolves Sulphur and phosphorus, forming a permanent solution. Chloride of Sulphur smokes violently in the open air, and soon flies off, leaving crystals of Sulphur if it contains that substance in solution. When dropped into water it is decomposed, Sulphur being evolved. When dropped into nitric Acid a violent effervescence is produced, and sulphuric Acid is formed. This substance is supposed to consist of one atom of chlorine + two atoms of Sulphur.

The *chloride of Sulphur* formed by Davy's process is described as having properties similar to those of the substance just described, and Davy seems to have considered the substances identical; but Thomson supposes the latter to contain one atom of each of the elements.

(381.) F. Unknown.

(382.) G. Iodide of Sulphur was first described by Gay Lussac. (d.) It is supposed to contain one atom of each element; and is formed simply by heating iodine and Sulphur together in a glass tube. This compound has the appearance of sulphurate of anti-mony.

(383.) H. Sulphur combines with hydrogen, forming a peculiar substance formerly called sulphuretted hydrogen Gas, but now more appropriately hydro sulphuric Acid. In fact, hydrogen and Sulphur unite in two proportions. See subsect. 5.

The combination of Sulphur with carbon forms a substance of considerable interest. It was first described by M. Clement and Desormes, (e.) though it had been obtained by Lampadius in 1796. (f.) These Chemists obtained it by adding Sulphur to charcoal contained in a porcelain tube at a red heat. This process is rather uncertain and inconvenient. The writer of this Synopsis has obtained it readily and in large quan-

Chemistry. city by fixing a tubulated porcelain retort filled with bits of charcoal into a Black's portable furnace: to the tubulure of the retort an earthen tube a foot long was luted and closed by a cork. Through this tube small fragments of Sulphur were dropped down upon the heated charcoal. The sulphuret of carbon as it formed passed off in vapour by the beak of the retort, into which a glass tube was fixed and terminated under water. Here the sulphuret was condensed in drops, and remained at the bottom of the jar of water. To obtain the Liquid in a state of purity, a subsequent distillation at a very gentle heat ( $110^{\circ}$ ) is required.

*Bisulphuret of carbon* is a limpid Liquid, of Specific Gravity about 1.27. It boils at  $105^{\circ}$  or  $110^{\circ}$ , and does not freeze at  $-60^{\circ}$  Fahrenheit. It is so extremely volatile as to produce a greater degree of cold by its evaporation than any other known substance. Thus mercury may be frozen conveniently by covering the bulb of a thermometer with cotton wool moistened with this substance, and placed under the receiver of an air-pump. In the open air it takes fire at a very low temperature, and burns with a blue flame; is not soluble in water, but readily so in ether and alcohol. It is considered to consist of one atom of carbon + two atoms of Sulphur. Consult also ref. (9.)

Sulphur combines with phosphorus (356.) and selenium, but not with boron, silicon, or nitrogen.

(384.) L. Sulphur combines readily with almost all the metals, and in some cases these compounds are regulated by the laws of definite proportions.

(385.) K. Under this head there is not much to notice: by digestion with nitric Acid, Sulphur itself undergoes acidification, and is converted into Sulphuric Acid. Upon the earthy oxides Sulphur exerts no action; but at a temperature sufficiently elevated it acts upon all other oxides, in some cases reducing the metals, in others forming sulphurets.

(386.) L. Sulphur is readily recognised by its Physical properties; or, if in small quantity, it may be acidified by nitric Acid, and tested with great accuracy as Sulphuric Acid.

(387.) M. This substance is of great service in the Arts: the Sulphurous Acid produced in its combustion is used to bleach woollen substances and straw bonnets. With nitre and charcoal it forms gunpowder. It is an important ingredient in the cement used in joining iron pipes for Gas and water. In Medicine it is applied externally in cutaneous disorders. Internally, it is sometimes given in visceral obstructions, and as an alterative.

It possesses a rapid effect in counteracting the specific action of mercury on the system. For this purpose sulphuret of potash is perhaps the best form of exhibition.

#### Subject 1.—Hyposulphurous Acid.

(388.) The Salts formed by this Acid were first noticed by M. Thenard (h.): its relation to the other compounds of sulphur and oxygen were then pointed out by Dr. Thomson; and lastly Mr. Herschel (i.) added very considerably to our knowledge of its compounds and their mode of decomposition.

*Hyposulphurous Acid* may be formed by passing a current of sulphurous Acid into a solution of the hydrosulphuret of lime or strontia; or by digesting sulphur in a solution of any sulphate, or by digesting iron-filings in a solution of sulphurous Acid in water. In all these cases a solution of a hyposulphite of the base

remains. It appears, however, that the Acid itself cannot exist permanently in a free state; for if a hyposulphite be decomposed by sulphuric or muriatic Acid, the Hyposulphurous Acid at the moment of quitting the base resolves itself into sulphurous Acid and sulphur. Mr. Herschel did indeed obtain free Hyposulphurous Acid by adding a slight excess of sulphuric Acid to a diluted solution of the hyposulphite of strontia; but decomposition speedily took place at common temperatures, and was instantly effected by heat.

#### Subject 2.—Sulphurous Acid.

(389.) Sulphurous Acid Gas is produced whenever sulphur is burned in common air or oxygen Gas; but it is most readily obtained by putting three parts of Sulphuric Acid and two parts of mercury into a small glass retort. The heat of an Argand lamp produces a copious evolution of the Gas, which ought to be received over mercury. Here a part of the sulphuric Acid gives up its oxygen to the metal, and is reduced to the state of Sulphurous Acid, while the remainder unites to the oxidated metal, and produces a residuum of sulphate of mercury in the retort.

This Gas has a pungent and very characteristic odour: it extinguishes combustion, and is not itself combustible. It is quite unfit for respiration. Water, especially when hot, is capable of dissolving a considerable quantity of this Gas. The bleaching properties of burnt sulphur already mentioned (387.) are due to its action; and it is singular that if litmus-paper be so bleached, the colour seems not to be absolutely destroyed, but may be again developed either by an Acid or alkali. If moisture be present, Sulphurous Acid Gas will unite with oxygen, and pass to the state of Sulphuric Acid. Nitric Acid, or oxide of manganese, produce the same effect. Of all the Gases, this one is most readily condensed into the liquid form. Mr. Faraday effected this by a pressure equivalent to two atmospheres; and M. Bussy (k.) produced the same effect under the ordinary atmospheric pressure by subjecting it to the cold produced by snow and salt. This Acid unites with bases, and produces Salts called sulphites. It is believed to consist of equal volumes of sulphur, vapour, and oxygen, or of sulphur one atom + oxygen two atoms

#### Subject 3.—Hyposulphuric Acid

(390.) MM. Welter and Gay Lussac first discovered this Acid, and formed it by passing a current of sulphurous Acid Gas through water in which finely-powdered peroxide of manganese was suspended. A neutral solution of hyposulphate and sulphate of manganese is produced. The solution is to be concentrated, and then by adding an excess of pure baryta to the heated solution, and agitating it well, the oxide of manganese is separated, as also the insoluble sulphate of baryta. The filtered Liquid will contain hyposulphate of baryta and some excess of that earth in solution. This excess may be removed by a stream of carbonic Acid, and an excess of that Acid may be got rid of by boiling. The pure hyposulphate of baryta is then to be crystallized, redissolved in water, and the baryta precipitated by cautiously adding the requisite quantity of sulphuric Acid. The filtered Liquid is to be concentrated by sulphuric Acid placed in the receiver of an air-pump till it has a Specific Gravity 1.847.

**Chemistry.** This Acid is not affected by oxygen Gas, chlorine, or concentrated nitric Acid. It dissolves zinc with evolution of hydrogen Gas. It saturates bases forming Salts. Those of lime, baryta, strontia, and the protoxide of lead, are soluble, thus forming a marked distinction between themselves and the sulphates of the same bases. Hyposulphuric Acid is supposed to consist of sulphur two atoms + oxygen five atoms, (l.)

*Subsect. 4.—Sulphuric Acid.*

(391.) A. As far as is known, Sulphuric Acid was first obtained by Basil Valentine, in the XVth century. He procured it by the dry distillation of sulphate of iron. Subsequently it has been obtained by other processes, and is extensively employed in the Arts. It is found in combination with bases in several mineral substances, but does not exist free in nature, except possibly in small quantities among the products of active volcanoes.

(392.) B. Sulphuric Acid is now chiefly made by burning a mixture of one part of nitre with six or eight parts of sulphur in large leaden chambers, having the floor covered with a thin stratum of water. (m.) The Liquid thus produced consists of a solution of Sulphuric Acid in water. By subsequent evaporation the greater part of the water is driven off, and a concentrated Sulphuric Acid remains. In its highest state of concentration liquid Sulphuric Acid contains dry Sulphuric Acid one atom + water one atom.

(393.) At Nordhausen, in Thuringia, a strong liquid Sulphuric Acid is prepared from sulphate of iron by dry distillation, in earthen retorts. This Acid may be put into a glass retort, to which a large tube is attached and surrounded with ice. Ignited charcoal is placed under the retort, and the Liquid being brought to ebullition, vapours of an hydrous Sulphuric Acid pass over, and are condensed in the cold tube. This Acid, at a temperature below 77° Fahrenheit, is solid, white, and opaque, at 77° it fuses and forms a Liquid, which strongly refracts light; having a density of 1.57. At a higher temperature it is volatile, so as indeed not to be easily fused, except under some pressure. This substance possesses strongly acid properties, and attracts moisture with great avidity. (n.) It consists of sulphur one atom + oxygen three atoms.

(394.) C. Sulphuric Acid is an oil-like fluid, and when pure is colourless. It has a very strong affinity for moisture, and produces, when mixed with water, a very considerable degree of heat. Dr. Ure states that 73 parts by weight, mixed with 27 parts of water, exhibit this property in the most striking manner. The Specific Gravity of the strongest liquid Acid is 1.850; but Dr. Ure states that if pure it is not beyond 1.8485. Mr. Dalton has given a Table exhibiting the real Acid in mixtures of Acid and water of different densities. See Part V. Table IV. Consult, also, Mr. Parke's Essay, (o.) and Dr. Ure's Paper. (p.) Liquid Sulphuric Acid may be frozen by artificial cold. In distilling over Sulphuric Acid from glass vessels there is great danger of the vessels being broken by the violent detonations with which the heated Liquid bursts into vapour; this may, however, be remedied by placing in the retort a few fragments of pounded glass, or platinum wire: the sharp points of these bodies determining the evolution of vapour in smaller bubbles, and, therefore, with less violence of effect. The nature of this action, with reference to some other curious points in the extrication

of Gases, and of vapours arising during ebullition, has been examined by Gay Lussac. (q.) Sulphuric Acid is decomposed by the Voltaic pile

(395.) D. None.

(396.) E. None.

(397.) F. Unknown.

(398.) G. None

(399.) H. Of these substances not one decomposes Sulphuric Acid at common temperatures, but all with the exception of nitrogen, and possibly selenium, decompose it when aided by heat. Hydrogen effects this at a low red heat; and water, and sulphurous Acid Gas, or sulphur results. Carbon, at a high temperature, decomposes it, producing gaseous carbonic Acid, and sulphurous Acid. The action of phosphorus is analogous; and that of boron would be so in all probability.

(400.) I. Potassium and sodium decompose Sulphuric Acid with violence at all temperatures. Zinc, iron, and probably manganese, exert little action on Sulphuric Acid at common temperatures; but by the help of a moderate heat they decompose it, with evolution of hydrogen Gas, and become sulphates of the metals respectively. The hydrogen results chiefly from the decomposition of the water present, so that the process succeeds best by diluting the Acid when obtaining that Gas is the end required.

Tin, and the metals of the last three classes, do not act at all on Sulphuric Acid at ordinary temperatures; but above 212° Fahrenheit all do so except chromium, tungsten, columbium, titanium, uranium, cerium, osmium, palladium, rhodium, platinum, gold and iridium.

(401.) K. Sulphuric Acid never performs the part of a base, and its action upon other Acids is entirely of the nature of decomposition, dependent upon the elements of which they may be composed. With bases it forms numerous and important Salts, which we have not space here to enumerate.

(402.) L. Sulphuric Acid is most readily and distinctly recognised by the precipitate which it gives with borytic water, or solution of barytic Salts. The white powder so produced is insoluble in nitric Acid, but by being heated with charcoal, it is converted into a sulphuret.

(403.) M. Sulphuric Acid is largely employed in the Arts; as a lixivium in dyeing, and for dissolving indigo. Sometimes, also, in tanning leather. It serves also to decompose other Salts, whose Acids are required free. In practical Chemistry, also, its uses are numerous and extensive. Vinegar is often adulterated with it; and a sort of lemonade is made with this as a cheap substitute for citric Acid.

*Subsect. 5.—Compounds of Sulphur with Hydrogen.*

In examining this part of our subject we encounter some difficulties, which chiefly arise from the confused state of our nomenclature; and in attempting briefly to dispel them, we shall be under the necessity of making a slight change in the language of some Chemists; but we trust that no confusion will thence arise, as we shall carefully present the synonymes of other authors.

Sulphur and Hydrogen unite in two proportions;—are these to be called Sulphurets of Hydrogen, or Hydrosulphurets of Sulphur? The former was the plan at first adopted, and Berthollet, to preserve a distinction, employed the

**Chemistry.** terms "*Hydrogène Sulphuré*," and "*Soufre Hydrogéné*." The proportions are now known to be Hydrogen one atom + sulphur two atoms; and Hydrogen one atom + Sulphur one atom. The former compound unites with bases, but it has not been shown to possess acid properties; though in some sense it is probable that it does so. The latter also unites with bases, and possessing decidedly acid properties, Gay Lussac proposed to call it Hydrosulphuric Acid; thus recognising that Hydrogen is its acidifying principle, and preserving the analogy for Hydriodic, Hydrochloric Acid, &c. &c. If we consider the compound of one atom Hydrogen + two atoms Sulphur not an Acid, we may consistently with our plan call it Hydruret of Sulphur; but if we deem it an Acid, we may call it Hydrosulphurous Acid. For the second compound consisting of one atom of Hydrogen + one atom of Sulphur, we unhesitatingly adopt Gay Lussac's name of Hydrosulphuric Acid.

*Hydruret of Sulphur, or Hydrosulphurous Acid.* (*Soufre Hydrogéné of Thénard; Hydrosulphurous Acid of Thomson; Bisulphuretted Hydrogen of Henry.*)

(404.) The following are the properties of this substance as detailed by Berthollet, (s.) and abstracted by Dr. Henry. (t.)

"This substance is obtained when the compound produced by boiling Flowers of Sulphur with liquid potassa is poured by little and little into muriatic Acid. A very small portion only of Gas escapes; and while the greater part of the Sulphur separates, one portion of it combines with the Hydrosulphuric Acid, assumes the appearance of an oil, and is deposited at the bottom of the vessel. Or dissolve Sulphur in a boiling solution of pure potassa; and into a phial, containing about one-third its capacity of muriatic Acid, of the Specific Gravity 1.07, pour about an equal bulk of the liquid compound. Cork the phial, and shake it; the Hydruret of Sulphur gradually settles to the bottom in the form of a brown, viscid, semifluid mass; its properties are the following.

1. "Its taste and smell resemble those of putrid eggs, but are less offensive. Its precise Specific Gravity is unknown, but it is heavier than water, and descends through it. It is inflammable, and burns in the air with a smell of Sulphurous Acid.

2. "If gently heated, Hydrosulphuric Acid Gas exhales from it, the bisulphuret loses its fluidity, and a residue is left consisting merely of Sulphur.

3. "It combines with alkalis and earths."

Its constitution has been already described.

(405.) The combinations of this substance with alkalis and earths might be called Hydrosulphurets, or Hydrosulphites, according as we deemed the substance itself an Acid or not; but unfortunately the former term has been by some applied to the true Hydrosulphates. In some Treatises the combinations now before us are called Hydroguretted Sulphurets, a term we cannot employ consistently with our plan.

The *Hydrosulphurets* then, or *Hydrosulphites*, are "formed by boiling along with a sufficient quantity of water, the alkaline or earthy base, with Flowers of Sulphur. Thus a solution of pure potassa, pure soda, or of baryta, or strontia, may be changed into a Hydrosulphuret.

"Another method of forming by a very simple process the Hydrosulphurets consists in digesting in a

gentle heat a Hydrosulphate with powdered Sulphur, an additional portion of which is dissolved, while part of the Hydrosulphuric Acid Gas escapes.

"Hydrosulphurets have the following properties.

1. "They have a deep greenish yellow colour, an acid and intensely bitter taste, and an excessively offensive smell.

2. "They deposit Sulphur when kept in close vessels, become much more transparent and lighter coloured, and less offensive to the smell.

3. "They rapidly absorb oxygen from the atmosphere and from oxygen Gas. Hence their employment in Eudiometry.

4. "On the addition of dilute Sulphuric, or Hydrochloric, or of certain other Acids, they are decomposed. Hydrosulphuric Acid Gas is evolved, and Sulphur is precipitated.

5. "When boiled in contact with filings of silver, or of copper, and of those metals only, Vauquelin found that they lose their excess of Sulphur, and become Hydrosulphates."

*Hydrosulphuric Acid. (Sulphuretted Hydrogen.)*

(406.) This Gas, though known before, was first examined with care by Scheele about 1777. It is frequently produced during the spontaneous decomposition of organic substances, and from the receptacles for excrementitious matters. Also as an element in numerous mineral waters, such as those of Barreges, Schinznach, Harrowgate, &c.

For Chemical purposes, it is most readily procured by heating powdered sulphuret of antimony in a retort with four or five times its weight of strong muriatic Acid. Or a protosulphuret of iron may be made by placing a mixture of two parts of iron filings and one part of sulphur in a common earthen or iron crucible, well closed, and then giving it a low red heat. The sulphuret thus formed may be pulverized when cold, and acted upon by muriatic Acid diluted with thrice its weight of water.

Hydrosulphuric Acid Gas consists of one atom of each of its elements, occupying the same volume as the hydrogen of which it is formed. This Gas is without colour, but has a very peculiar and disagreeable taste and odour, similar to that of rotten eggs. At 50° Fahrenheit it may be reduced to a Liquid by a pressure of seventeen atmospheres. It extinguishes all burning bodies, but when ignited burns with a pale blue flame. It detonates by the electric spark when mixed with oxygen. This Gas has decidedly acid properties, as it reddens litmus-paper, and may be made to neutralize alkaline bases. Chlorine and iodine decompose it, separating the sulphur and producing hydrochloric or hydriodic Acid. An atmosphere in which this Gas abounds may be purified by chlorine in a very few minutes. Hydrosulphuric Acid produces very marked effects upon metals and metallic oxides. The sulphur entering into combination tarnishes gold and silver readily. White paint is immediately discoloured for a like reason. The most delicate test of the presence of Sulphuretted Hydrogen is to paint a piece of paper with flake white, (carbonated oxide of lead.) This is instantly coloured by Hydrosulphuric Acid Gas, even when, according to Dr. Henry, only a twenty-thousandth part of the volume of air consists of this Gas. Hydrosulphuric Acid Gas is one of the most deleterious that can be respired. Dupuytren and Thénard found that

Chemistry. air containing 1-1500th part instantly destroyed a small bird; 1-800th killed a dog; and 1-150th destroyed a horse. (r.)

(407.) The hydrosulphates, as the name implies, consist of combinations of Hydrosulphuric Acid (sulphuretted hydrogen) with bases.

This Acid combines with bases from the second class of metals, and, perhaps, also with glycyne and ythria; with oxide of zinc, with the protoxides of manganese and iron, the oxides of tin, and the protoxide of antimony. With the oxides of the last four classes, no such union is formed, for the oxides themselves are decomposed and sulphurets produced. The alkaline and earthy hydrosulphates are soluble in water, are colourless, and have a sharp and rough taste. The rest, which are insoluble, have neither scent nor taste; and three only, viz. those of iron, antimony, and tin, are coloured. All Acids except the carbonic decompose the hydrosulphates, by setting the Acid Gas free.

The hydrosulphates of potash, soda, barytes, strontia, lime, and magnesia are prepared by passing a current of the Gas through these substances dissolved or suspended in water by means of a Woulfe's bottle. The insoluble hydrosulphates are obtained by double decomposition.

The great and constant utility of the hydrosulphates as tests of metallic substances, will induce us to give a table of these indications. See Part V. Table V.

(408.) On the whole then it appears, that sulphur, Hydrosulphurous Acid, (hydroguret of sulphur, of some,) and Hydrosulphuric Acid (sulphuretted hydrogen of some) will all unite with metals and their oxides. In the first case, the result is a sulphuret; in the second, it is a hydrosulphide, or, as we might call it, a Hydrosulphuret; (hydroguretted sulphuret of some;) and in the last it is a hydrosulphate (hydrosulphuret of some.) The sulphurets can only continue stable in a dry state, for so soon as they begin to dissolve in water, that Fluid is decomposed, Hydrosulphuric Acid Gas is formed and evolved, while Hydrosulphurous Acid being also formed unites with the base. (t.)

#### References to § 6.

(a.) Nich. Jour. vol. ii. p. 102. (b.) Mém. d'Arcueil, vol. i. p. 161. (c.) Gehlen's Jour. vol. ix. p. 172; Elements, p. 280. (d.) An. de Ch. vol. xci. p. 22. (e.) An. de Ch. vol. xlii. p. 136. (f.) Crell's Annals, vol. ii. p. 136; and Gehlen's Jour. vol. ii. p. 192. (g.) Berthollet, Mém. d'Arcueil, vol. i. p. 304; Chzel, An. de Ch. vol. lxxiv. pp. 72. 113; Thenard, &c. An. de Ch. vol. lxxxii. p. 252; Berzelius and Marcet, Phil. Trans. 1813, p. 171. (h.) An. de Ch. vol. lxxxv. (i.) Edin. Phil. Jour. vol. i. pp. 8. 3-6. (k.) An. Phil. N. S. vol. viii. p. 307. (l.) An. de Ch. et de Phys. vol. x. p. 312. (m.) Parke, Chemical Essays, vol. ii. (n.) Bussy, An. de Ch. et de Phys. vol. xxvi. p. 411. (o.) Essays, vol. ii. p. 461. (p.) Jour. of Science, vol. iv. p. 127. (q.) Ency. Met. Art. Heat. (74.) (r.) Rouelle Macquer, Chem. Dic. vol. i. p. 520; Scheele, On Air and Fire, p. 186; Bergman, Opusc. vol. i. p. 233; Kirwan, Phil. Trans. 1786, p. 118; Van Troostwyck, &c. An. de Ch. vol. xiv. p. 294; Berthollet, An. de Ch. vol. xiv. p. 233; Berzelius, Afhandl. vol. ii. p. 78; Gay Lussac, &c. Recherches, P. C. vol. i. p. 191; Davy, Phil. Trans. 1812, p. 412; Faraday, Phil. Trans. 1823, p. 192; Thom-

son, First Principles, vol. i. p. 217. (s.) An. de Ch. vol. xxv. p. 247. (t.) Elements, vol. i. p. 446; An. de Ch. vol. xxv. p. 247, &c.; An. de Ch. et de Ph. vol. vi. p. 322.

#### § 7.—Selenion.

(409.) A. Messrs. Gahn, Eggertz, and Berzelius are the proprietors of a manufactory of sulphuric Acid from the sulphur obtained in the copper-mine of Fahlun, in Sweden. In examining, in 1817, the brown residuum or sediment on the floor of a leaden chamber in which the sulphur is burned, Berzelius found that this substance, besides containing sulphur and other impurities, consisted in part of a peculiar substance, which proved to be a simple body heretofore unknown. He considers it a metal, and named it *Selenium*, from *σεληνη*, the moon, in consequence of its properties greatly resembling those of tellurium. In describing these properties, we are inclined to think that many will agree with us in removing it from the rank of a metal, and placing it among the combustible nonmetallic elements, in which we follow the plan of Thomson and Thenard. Selenium has hitherto been found principally in two minerals, the seleniuret of copper, and eubairite, a seleniuret of silver and copper, discovered by M. Berzelius in the abandoned copper-mine at Skrickerum, in the parish of Tryserum, in Smoland. The pyrites of Fahlun also contain it, and it has subsequently been recognised with sulphur in the volcanic districts of Italy.

(410.) B. The residuary powder which contains the Selenium has also an admixture of several other substances; viz. sulphur, mercury, lead, tin, iron, copper, zinc, and arsenic. For the complete process of separation, which is very complex, we must refer to the original Memoir of Berzelius. (a.) The following are its principal features. The reddish brown powder is digested in nitro-muriatic Acid to acidify the Selenium. Water is then to be copiously added, and the Liquid filtered. To this clear solution, which contains the Selenic Acid, together with some other substances, a solution of muriate of ammonia is then added in excess, by which the Selenium is thrown down pure in a pulverulent state, and is to be well washed with water, then dried and carefully fused.

(411.) C. Selenium is at ordinary temperatures a solid, tasteless, and scentless substance, of a deep chocolate brown colour with a sort of metallic lustre. It is brittle, has a conchoidal fracture producing a lead-coloured surface. The powder is of a deep red colour, and thin fragments transmit the red rays of light. It may be scratched with a knife. Selenium does not readily crystallize, but the forms it is supposed to assume are those of a cube, and a quadrangular prism with a pyramidal summit.

It is a very bad conductor of heat, and is a nonconductor of electricity, which seems a strong argument against its being a metal; and yet, on the other hand, Berzelius was not able to produce electric excitement in it by friction. Upon being heated Selenium softens; at 212° it becomes semifluid, and is quite liquid at 230° Fahrenheit. It may be kneaded between the fingers and drawn out into threads like sealing-wax. Filaments so produced are red by transmitted light, and their reflected light is grey. In a retort, Selenium boils at a heat below redness, and its vapour is a yellow, deeper in colour than chlorine Gas, but not so deep as



**Chemistry.** the vapour of sulphur. This vapour condenses in the neck of the retort in black drops, similar to those produced in the distillation of mercury. But when this substance is heated in large vessels, or in the open air, the condensed vapour actually becomes a fine powder of its appropriate red colour: a formation analogous to the Flowers of sulphur. Selenion when heated dissolves in the fat oils, in lard, and in wax, but is not soluble in the essential oils.

(412.) D. Selenion has no action on oxygen Gas without the aid of heat; but by the help of that agent it may be made to combine with oxygen in two proportions. Fill a balloon with oxygen Gas, and put into it a small piece of Selenion, allowing the balloon to communicate with a gasometer of oxygen Gas by a tube. Then apply a gentle heat to the matrass. If the balloon be only about an inch in diameter, the Selenion will inflame the moment it enters into ebullition, and will burn with a feeble flame, white at its base, and greenish at its apex. By this combustion *Selenic Acid* is produced, which sublimes and is condensed in a white powder, while the Selenion totally disappears. Vide subsect. 1.

But if this experiment be made in a large balloon holding some pints, the Selenion does not take fire, but unites all at once with the oxygen; and in this case, instead of the Acid there is an oxide of Selenion formed which is Gaseous, and has the smell of decayed cabbage, or horse-radish. Berzelius attributes this variety of action to the pressure existing in the small vessel, which does not suffer the dispersion and volatilization of the oxide as in the more roomy one. The Gaseous oxide of Selenion is colourless; does not affect vegetable colours; is very slightly absorbable by water, but communicates to it its own peculiar odour; does not unite with alkalis. Berzelius thinks that it can only exist as a Gas.

(413.) E. Berzelius placed Selenion in a glass tube, and passed a current of chlorine through the tube as long as the Selenion continued to absorb any of the Gas. The chloride so formed was at first a Liquid, but gradually became a white Solid, as it approached the point of saturation. It contracts slightly by heat but does not melt, and then sublimes in the form of a yellow vapour, condensing on any cool part of the apparatus in small white crystals. It dissolves in water with slight effervescence, and the selenic and hydrochloric Acids are found mixed with the water.

(414.) F. G. Unexamined.

(415.) H. Selenion has been combined with hydrogen, phosphorus, and sulphur. By the first *hydroselenic Acid* is produced. See subsect. 2. By dropping Selenion into melted phosphorus it rapidly dissolves, forming at the same time a compound which sinks in red streaks passing through the phosphorus. But these two substances will unite in any proportion by fusion. Berzelius, however, supposed that he obtained a definite phosphuret of Selenium, and he found that by digesting this phosphuret in water the water was decomposed, hydroselenic Acid Gas was evolved, and some Selenium precipitated.

Sulphuret of Selenion is formed by passing hydrosulphuric Acid Gas through an aqueous solution of selenic Acid. The Liquid becomes turbid and yellow; and the addition of a little hydrochloric Acid causes the sulphuret of Selenion to fall down as a deep orange-

coloured powder. This sulphuret softens at 212° Fahrenheit, and liquefies by a few degrees further accession of temperature. It may be boiled and distilled over. The portion so distilled is transparent, of a reddish orange colour, resembling melted orpiment. It is not acidifiable by nitric Acid, but is more powerfully affected by the nitro-muriatic. It is soluble in caustic fixed alkalis, and in the hydrosulphurets, but again precipitable by Acids as a sulphuret of Selenion.

The relations of Selenion with carbon, boron, and silicon have not been investigated; but with the first of these substances Berzelius thinks it may form a substance analogous to the sulphuret of carbon.

(416.) I. We are at present acquainted with fifteen metallic seleniurets, and for this knowledge we are indebted to Berzelius. These seleniurets are of potassium, zinc, iron, tin, arsenic, antimony, cobalt, bismuth, copper, lead, tellurium, mercury, silver, palladium, and platinum; and it is probable that this substance will be found to unite with all other metals on trial.

The metallic seleniurets seem to be subject to the same Chemical laws with the metallic sulphurets. They are similarly affected by air, water, oxygen Gas, and by changes of temperature. They are also definite compounds, and, as in the case of the sulphurets, it seems probable that there exists more than one definite compound to each metal.

The best process for obtaining the seleniurets as definite compounds is to precipitate their metallic solutions by hydroselenic Acid. By this method the deuto-seleniurets are formed. To obtain the proto-seleniurets we must heat the metals in contact with Selenion, and then drive off the excess of the latter by heat.

(417.) K. The nitric and hydrochloric Acids, when cold, do not act upon Selenion, but with the aid of heat they rapidly convert it into selenic Acid.

(418.) L. Selenion is most easily recognised by the very disagreeable odour of decayed horse-radish which a very minute quantity produces when placed in the exterior flame of the blowpipe.

(419.) M. The rarity of Selenion would preclude its application to the Arts, even if it were found serviceable. Its Medicinal properties are unknown; but the fumes of hydroselenic Acid inhaled appear to be extremely pernicious, and Berzelius thinks that a very small quantity would prove fatal to animal life.

#### Subsect. 1.—*Selenic Acid.*

(420.) A. B. This Acid was discovered by Berzelius, and one method of obtaining it has been already described; (412.) but in practice it is found more convenient to add one part of selenion to three or four parts of pure nitric Acid. The mixture is gradually raised to ebullition, and at that temperature the selenion rapidly decomposes the nitric Acid, seizing on a part of its oxygen. When all the selenion is dissolved, it is entirely acidified: the solution is to be evaporated to dryness in a porcelain capsule, and is then pure Selenic Acid. But if the solution be only concentrated and not evaporated, the Selenic Acid will, upon cooling, crystallize in six-sided prisms. By a considerable increase of heat this Acid parts with water, and lastly rises in a yellow vapour. This vapour condenses on the upper part of the apparatus in long, slender, tetrahedral prisms.



Chemistry.

(421.) C. Selenic Acid has no scent, but a strongly acid taste, and reddens vegetable blues. It is volatilized but not decomposed by heat. It attracts some moisture from the air, but does not actually deliquesce. It is very soluble in cold water, and still more so in hot water. Alcohol also dissolves it readily. Hot water, which has been saturated with it, lets fall the Acid in small crystals, if rapidly cooled, but in striated prisms when slowly so.

(422.) D. None.

(423.) E. Selenic Acid is capable of absorbing chlorine. The compound so formed is capable of decomposing water, and upon this decomposition hydrochloric and Selenic Acids are found in the solution.

(424.) F. G. Unexamined.

(425.) H. Thenard says, "It is probable that with the aid of heat, hydrogen, boron, carbon, and phosphorus would decompose the Selenic Acid."

(426.) I. The same able Chemist considers it certain that the metals of the first four classes will decompose Selenic Acid at a high temperature, and states that if the Acid be dissolved in water, and then a little hydrochloric Acid be added to the solution, a plate of zinc or iron will precipitate the selenion in red, brown, or dark-grey flocculi.

(427.) K. Selenic Acid, in any solution, is easily decomposed by rendering the solution slightly acid, and then adding sulphate of ammonia. The sulphurous Acid takes the oxygen and becomes sulphuric Acid, and the selenion falls down as a dark powder. The strong fixed Acids drive off Selenic Acid from bases with which it may be combined.

The Selenic Acid unites with bases in more proportions than one; but for these Salts we must refer the reader to the *Memoirs* of Berzelius, or to Thenard, *Traité de Chimie*, art. 877. Bis.

(428.) L. The nitrates of silver and lead are the most marked tests of Selenic Acid.

#### Subsect. 2.—Hydroselenic Acid.

(429.) A. Hydroselenic Acid is, as the name implies, an Acid compounded of hydrogen and selenion, analogous to the hydrosulphuric, hydriodic, hydrochloric, &c. For the knowledge of this proximate element we have still to refer to the experiments of Berzelius.

(430.) B. The best process for obtaining this Acid in the Gaseous state is to act upon the seleniuret of iron with hydrochloric Acid in a glass proof or small retort; but as the Gas is soluble in water, it must be collected over mercury. In this process, water is decomposed, protoxide of iron is formed, which combines with the hydrochloric Acid, and Gaseous Hydroselenic Acid is evolved. M. Thenard, however, states that in this process another Gas is also formed, which is neither soluble in water nor in alkalis, and that, therefore, to obtain the Hydroselenic Acid quite pure, it might be advisable to employ the seleniuret of potassium.

(431.) C. This Gas is colourless, and reddens the tincture of turmsole. Its odour, which at first resembles that of hydrosulphuric Acid Gas, shortly changes to a sharp astringent sensation, not entirely devoid of pain. The eyes become red and inflamed, and all sense of smell is for a time destroyed. A bubble the size of a small pea is sufficient to produce these effects. So at least M. Berzelius found, to such an extent, that he was able to apply the strongest solution of ammonia under

his nose, and did not recover any power of sensation in it until five or six hours had elapsed. At the same time a very copious defluxion from the mucous membrane of the nostrils came on and continued fifteen days. Similar, though less violent, effects took place on subsequent occasions, when bubbles no larger than a pin's head escaped accidentally, and became mingled with the atmospheric air. These were not all the ills that resulted from breathing this noxious Gas; for even in this mitigated form M. Berzelius perceived the approach of a dry fixed cough, which came on in half an hour, remained a long time, and finally was accompanied by an expectoration, giving a taste precisely like that of the vapours of a boiling solution of corrosive sublimate, and did not depart until he had applied a blister to his chest. In short, this admirable Chemist considers this the most noxious Gas at present known. Water absorbs a greater proportion of this Gas than of the hydrosulphuric Acid; but even when it holds half its volume in solution, the water has acquired but little smell. The Liquid so formed causes an indelible brown mark on the human skin, and is itself colourless if the water be quite free from air; but if left exposed, the Hydroselenic Acid is decomposed, and the Liquid becomes turbid from the flocculi of selenion that present themselves. Hence it is apparent why a solution of this sort becomes turbid next to the exposed surface first.

(432.) D. E. F. G. H. I. Imperfectly known.

(433.) K. Nitric Acid, when added in small quantity to the aqueous solution of Hydroselenic Acid, produces no effects.

(434.) L. The aqueous solution of Hydroselenic Acid causes precipitates in almost all the metallic solutions of the four last classes. These precipitates are for the most part black or brown, and take a brilliant metallic lustre by friction with polished hæmatites. Those, however, of zinc, manganese, and cerium are to be excepted; they are flesh-coloured, and are supposed to be hydroseleniurets of the oxides, while the others are metallic seleniurets. Consequently Hydroselenic Acid will for the most part decompose the oxides of the last four classes, even when united with the strongest Acids.

#### References to § 7.

(a.) Berzelius, *An. de Ch. et Ph.* vol. ix. pp. 160. 225. 337., or *An. Phil.* June, August, October, December, 1819, and June, 1820; Rose, *An. de Ch. et Ph.* vol. xxix. p. 113.

#### § 8.—Nitrogen.

(435.) A. This Gas was first discovered in 1772 by Professor Rutherford of Edinburgh. Scheele also had made himself acquainted with it previous to 1777. Nitrogen forms a very considerable proportion of the atmosphere in which we exist. Lavoisier called it azote, from its not having the power of supporting animal life.

(436.) B. There are several methods employed for procuring Nitrogen Gas.

1. Let equal weights of iron-filings and sulphur be made into a paste with water, and let the vessel containing this paste be placed on a stand over the pneumatic trough. Invert over it a jar of common air, and let it stand for a day or two. One-fifth of the volume of the air will disappear, and the remainder is Nitrogen Gas.

**Chemistry.** 2. Phosphorus burned in a close vessel of atmospheric air over water removes the oxygen and leaves the Nitrogen. The residual Gas should be well agitated with water to remove the phosphoric Acid formed.

3. Nitrogen may also be obtained by putting some lean beef into a glass proof with very dilute nitric Acid. A heat of about 1000° disengages the Gas, which must be collected over water.

4. But perhaps the most speedy way of obtaining it is to pass nitrous Gas copiously through a solution of protosulphate of iron. An ounce or two of this solution is then to be put into a phial, which must be closely corked or stopped with the thumb and well shaken; the phial is then to be inverted with its neck in another portion of the solution and unstopped, a fresh portion of the Liquid will enter to supply the absorption that has taken place. By a few repetitions of this process all the oxygen Gas will be removed, and pure Nitrogen will remain.

(437.) It has been supposed by very able Chemists, Davy and Berzelius especially, that Nitrogen is a compound body. Berzelius thus reasons on theoretical grounds chiefly: and Davy from a very curious experiment made with the Voltaic pile. Let a small hole be made in the surface of a lamp of muriate of ammonia, and in this hole place a globule of mercury. Connect the saline mass with the positive pole of the battery and the mercury with the negative pole; an action is immediately perceived in the metallic globule, its volume becomes enlarged, and more solid ramifications are perceptible in the fluid metal. This enlargement sometimes extends to ten times the original volume of the mercury. When completed, the amalgam (if such it be) is of the consistency of butter. It soon, however, returns to its original state by the formation of films of saline matter over its whole surface. The best experimentalists, however, could only obtain mercury, hydrogen, and azote from the amalgam so formed. (a.)

(438.) D. In speaking of Nitrogen with reference to oxygen, we are first called upon to mention the great mass of our atmosphere, which consists almost entirely of these two Gases: but from the importance of this agent we shall consider its properties apart in subject. 1.

When Nitrogen and oxygen are mixed together, no combination takes place. But when either of the elements is presented to the other in a state of condensation, or having the repulsive force of its molecules diminished by a decrease of heat, a union is effected, and the nature of the resulting compound is dependent upon the respective proportions of the two elements. Some of these combinations are always Gaseous, others, though in themselves Gaseous also, are always seen in combination with so much of the elements of water as to be Liquids.

The following is a synoptic view of the compounds of Nitrogen and oxygen:

	Atoms or volumes.		Weights.	
	Nitrogen.	Oxygen.	Nitrogen.	Oxygen.
Nitrous oxide.....	1	+	1	14 + 8
Nitric oxide.....	1	+	2	14 + 16
Hyponitrous Acid..	1	+	3	14 + 24
Nitrous Acid.....	1	+	4	14 + 32
Nitric Acid.....	1	+	5	14 + 40

These substances will be noticed in subjects. 2, 3, 4, 5, and 6.

(439.) E. Chlorine and Nitrogen, when placed in

contact, have no mutual action on each other, provided that both Gases are perfectly dry. A compound of these Gases may, however, be produced by passing a current of chlorine Gas through a solution of any ammoniacal Salt. The most convenient process for forming the chloride of Nitrogen, (to which the name of Azotane has been sometimes given,) is to fill a clean glass basin with a solution of muriate or nitrate of ammonia, containing about one part of the Salt dissolved in twelve parts of water, at 80° or 90° Fahrenheit. Over this solution let a tall jar of chlorine Gas be inverted. The Gas is gradually absorbed, and a film of an oil-like substance forms on the surface of the Liquid, and when a drop of sufficient size is collected, it sinks down to the bottom of the basin. The best way of removing a globule of this chloride of Nitrogen for any purpose of examination, is by a syringe made of a piece of glass tube, with a piston of tow wrapped round a wire.

Scarcely any known substance requires such care in its management as this Fluid, for it is the most violently detonating body known. It is not safe to make experiments on more than a single small globule not larger than a grain of mustard seed. M. Dulong, who discovered it, received a severe injury on the occasion; (b.) and Sir H. Davy did not fare better in repeating Dulong's experiments. (c.) A heat something below 212° Fahrenheit causes it to explode; also the contact of oil, phosphorus, and numerous other bodies; but the metals, alcohol, resins, sugar, or camphor, do not cause its explosion. Its Specific Gravity = 1.653, and it is supposed to contain Nitrogen one atom + chlorine four atoms. (d.)

(440.) F. Unknown.

(441.) G. Iodine and Nitrogen do not unite by mere contact; but when iodine is placed in a solution of ammonia in water, a brownish black iodide of Nitrogen is formed. This compound, like the chloride of Nitrogen, evaporates spontaneously in the open air, and detonates violently when heated or touched.

(442.) Of these substances, hydrogen and carbon unite with Nitrogen, the former producing ammonia, see subject. 7; the latter producing cyanogen, see subject. 8.

(443.) I. Of the metals it would seem that potassium and sodium may be considered as uniting in some manner with Nitrogen.

(444.) K. None.

(445.) L. Nitrogen is best recognised by its negative properties when in the Gaseous state: that it is not combustible, nor does it support combustion.

(446.) M. None.

#### Subject 1.—The Atmosphere.

(447.) "The Atmosphere is a collection of elastic Fluids, retained on the surface of the Earth by their gravitation. Its weight was first ascertained by Galileo, and applied by Toricelli to explain the rise of water in pumps, and of mercury in barometrical tubes; and by Pascal to the mensuration of the heights of mountains. At the level of the Ocean it is adequate to sustain a column of water having the altitude of 34 feet, or one of mercury of the height of 30 inches, and it presses with the weight of about 15 pounds on every square inch of surface. As we ascend, the Atmosphere decreases in density in a Geometrical proportion to

**Chemistry.** equal ascents. Thus, at three miles in height, the density of the Atmosphere is one-half what it is at the Earth's surface, or equal to a column of 15 inches of mercury; at six miles, the barometer would stand at one-fourth the usual height, or at  $7\frac{1}{2}$  inches; at nine miles of elevation, at  $3\frac{1}{2}$  inches; and at 15 miles nearly at one inch. Hence the greatest part of the Atmosphere is always within 15 or 20 miles of the Earth's surface; though from the refraction of the Sun's light, it may be inferred to extend from 40 to 45 miles in height. Beyond the former limit it appears highly probable, indeed, from the recent observations of Dr. Wollaston, (*Phil. Trans.* 1822,) that our Atmosphere does not reach at all; the force of Gravity downwards, upon a single particle, being there equal to the resistance arising from the repulsive force of the medium. We have no evidence, then, of the existence of similar matter round any other Planet; and, on the contrary, it has been ascertained by the observations of Captain Kater, that no retardation of the motion of Venus can be perceived in her progress towards the Sun, as would happen if the latter were encompassed by a refracting Atmosphere. The approach, also, of Jupiter's Satellites to the body of that Planet is uniformly regular, till they appear in actual contact, showing that there is not that extent of Atmosphere, which Jupiter should attract to himself from an infinitely divisible medium filling all space. These observations are favourable, as Dr. Wollaston remarks, to the existence of particles of matter no longer divisible, for if an elastic Fluid like our Atmosphere consist of such particles, we can scarcely doubt that all other bodies are similarly constituted; and may, without hesitation, conclude that those equivalent quantities, which we have learned to appreciate by proportional numbers, do really express the relative weights of elementary atoms, the ultimate objects of Chemical research.

"The great body of air constituting our Atmosphere is in a state of constant motion, not only from its accompanying the Earth in its rotation round its axis, but it flows also from the Equator towards the Poles, and contrariwise. Over the torrid zones the air is expanded by heat, and acquires a tendency to ascend, while the air from the temperate and frigid zones presses forward to supply the vacancy. In the torrid zones, the upper regions of the Atmosphere meet with less lateral pressure than is necessary to support them, and the air, therefore, overflows in both directions, so that currents Northward and Southward are established for supporting a temperature on the Earth's surface, approaching much more nearly to uniformity, than it could have been without such a provision of nature." Henry, *Chemistry*, vol. i. p. 287.

(448.) We may state in general terms that the mass of the Atmosphere consists of

	By weight.	By measure.
Nitrogen Gas . . . . .	77.50	75.55
Oxygen Gas . . . . .	21.00	23.32
Aqueous vapour . . . . .	1.42	1.03
Carbonic Acid . . . . .	0.08	0.10
	100.	100.

A small quantity of muriatic Acid is found in the air which is in contact with the sea; and the aqueous vapour is of course variable according to the temperature; but in other respects, a most singular and striking uniformity of composition has been found to pervade all

the air hitherto examined, whatsoever may have been the altitude from which it has been taken.

A pressure of 30 inches of mercury is supported by the ingredients already named in the following proportion, supposing each to act independently of the others.

Nitrogen Gas . . . . .	23.36 inches.
Oxygen Gas . . . . .	6.18 ditto.
Aqueous Vapour . . . . .	0.44 ditto.
Carbonic Acid Gas . . . . .	0.02 ditto.

Two opinions exist as to the mode in which these Gases exist together in the Atmosphere. The one that they are all in Chemical combination with each other; and the other opinion is, that no such combination takes place, but that the Atmosphere is merely a mechanical mixture of its ingredients. The latter opinion is ably supported by Mr. Dalton. (d.)

It is owing to the oxygen Gas in the Atmosphere, that it supports respiration and combustion. When rarefied, the air does not so readily afford the food that is necessary for burning bodies; and this seems to depend upon a want of condensation of that heat which is requisite for keeping up the combustion. Though it appears from Davy's experiments, that artificial condensation does not render it better fitted for that purpose.

(449.) The weight of 100 cubic inches of Atmospheric air at thermometer  $60^{\circ}$  Fahrenheit, and barometer 30 in. was said by Mr. Kirwan to be 30.92 grains troy. Sir H. Davy states it at  $55^{\circ}$  Fahrenheit, 31.10 grains. Sir George Shuckburgh at 30.5 grains, which is the estimate generally admitted. But Mr. Brande obtained by experiment 30.199 grains. Dr. Prout, whose accuracy and caution give his opinions a very great weight, is disposed to think that even Sir G. Shuckburgh's estimate is below the truth; and from him, if from any one living, we may look for a full and satisfactory investigation of this most important element in many of our calculations.

(450.) The determination of the quantity of oxygen Gas existing in a given portion of Atmospheric air, was early considered to be the same thing as ascertaining the purity of the air for respiration, &c.; and hence it obtained the name of *Eudiometry*. ( $\epsilon\upsilon\delta\iota\omicron\mu\epsilon\tau\rho\omicron\nu$ .)

Lavoisier exposed a quantity of mercury to heat in a retort which communicated with a jar of Atmospheric air; it will be obvious that the oxygen was removed, and the residuary Gas was nitrogen.

Berthollet employed a cylinder of phosphorus exposed to a known quantity of Atmospheric air confined in a tube over water. By the slow combustion of the phosphorus the oxygen was abstracted. A vapour of phosphorus, however, remains, forming the 1st part of the residuary Gas, for which allowance may be made. (c.) Seguin adopted the rapid combustion of phosphorus on similar principles. Several eudiometrical instruments have been constructed for the purpose of exposing a given volume of Atmospheric air to any liquid capable of absorbing and removing its oxygen. Such are Guyton's, (f.) Hope's, (g.) Henry's, (h.) and Pepy's eudiometer. (i.) The Liquid employed is either sulphuret of potash, sulphuret of lime, or a solution of sulphate of iron, saturated with nitrous Gas. But of all eudiometers that of Volta is, perhaps, the most satisfactory. It, with other instruments of the same sort, is described in our introductory Chapter on Apparatus.

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*Subject. 2.—Protoxide of Nitrogen. Nitrous Oxide Gas.*

(451.) A. This substance has not been found as a natural production. "Protoxide of azote was discovered by Dr. Priestly about the year 1776, and called by him *dephlogisticated Nitrous Gas*. He procured it first by keeping iron-filings in Nitrous Gas, and by keeping a mixture of iron and sulphur in the same Gas. (k.) The associated Dutch Chemists examined it in 1793, and demonstrated it to be a compound of azote and oxygen. (l.) But for a fuller account we are indebted to Sir H. Davy, who published an excellent Dissertation on it in the year 1800. He gave it the name of Nitrous Oxide." Thomson.

(452.) B. The best process for obtaining this Gas is to expose nitrate of ammonia to heat in a glass retort, connected with a Gasometer. The heat should not exceed 440° Fahrenheit, and may be conveniently produced by a well-regulated Argand's lamp. (m.) Should the air be required for respiration, it is well to let it stand some time in contact with water, which will absorb any Nitrous Gas, though at the same time it dissolves some of the Protoxide of Nitrogen. Carbonic Acid, another impurity, may be removed by a little caustic alkali or quick lime.

(453.) C. This Gas was reduced to a Liquid by Mr. Faraday under a pressure of at least 50 atmospheres. It partially supports combustion, for though a candle will not burn long in it, phosphorus burns with great vigour.

Its action with the other ultimate and proximate elements is not sufficiently important to be pursued by us here.

(454.) M. This Gas does not support life, for an animal confined in it dies; but its effect upon Man is so singular, that it frequently forms the subject of experiment. From two quarts to a gallon, or even more, may be breathed from a bladder or oil-silk bag, supplied with a stopcock. It is essential that the aperture be large, so as to supply a rapid torrent upon the lungs. The effects differ in different individuals, but for the most part they consist in a most delightful species of intoxication, which lasts only a few minutes, and goes off again without leaving any unpleasant or debilitating effects. From the excessive tendency to laughter which it produces, it has been sometimes called the *Laughing Gas*. For this point, see Davy's *Researches*, 1 vol. 8vo.

*Subject. 3.—Deutoxide of Nitrogen. Nitrous Gas.*

(455.) This Gas was known to Dr. Hales, but more systematically examined by Dr. Priestley. It is very readily obtained by pouring a little strong nitric Acid on copper-filings or quicksilver in a glass proof. When the Acid is of this strength, the Gas is copiously evolved without any adventitious heat; but if a dilute Acid be employed, a lamp-heat is requisite.

This Gas is only absorbable by water in a very slight degree; is not acid when pure; it will not support respiration, and extinguishes burning bodies in general, but phosphorus and charcoal, when previously lighted, burn vividly in it. When Deutoxide of Nitrogen is mixed with oxygen Gas, red fumes appear, heat is evolved, and if the just proportions be present for the formation of Nitrous Acid, the Gases disappear, and

that Acid is produced. The condensation of oxygen by this Gas forms the basis of its application to eudiometry; and as the process is extremely convenient and accurate, if judiciously managed, we recommend the examination of Mr. Dalton's remarks, as given by Dr. Henry, on this subject. (n.) This Gas is decomposed by many bodies which have a strong affinity for oxygen; for instance, iron-filings, sulphurous Acid, sulphuret of baryta and potassa, &c., potassium, sodium, and even arsenic or zinc. There is no action between this Gas and chlorine, unless moisture be present, in which case the water is decomposed; its oxygen joins to the Deutoxide of Nitrogen to form nitrous Acid; and its hydrogen forms hydrochloric Acid with the chlorine. It is not employed in Medicine, and its effect of asphyxia, when taken into the lungs, is supposed to be due to the formation of nitrous Acid by union with oxygen.

*Subject. 4.—Tritoxide of Nitrogen. Hyponitrous Acid Gas.*

(456.) If 400 volumes of nitrous Gas and 100 volumes of oxygen Gas be mixed together over a solution of potassa standing over mercury, there result 100 volumes of Tritoxide of Nitrogen. This Acid Gas combines with the potassa, but has not yet been exhibited in an isolated form; for if a stronger Acid be added to disengage it from the potassa, the Acid is resolved into nitrous Gas and nitrous Acid. A crystalline substance is formed by uniting this Acid with the sulphuric. Although the existence of this peculiar compound seems to be tolerably well established, we are not in possession of much information about it. We refer our readers to the writings of Gay Lussac (o.) and Dalton (p.) for further satisfaction.

*Subject. 5.—Tetartoxide of Nitrogen. Nitrous Acid Gas.*

(457.) According to Sir H. Davy, if two volumes of nitrous Gas be mixed with one volume of oxygen, both being quite dry, the remaining volume is 1.5; but according to Gay Lussac it is only one volume. Thus a deep orange-coloured Gas is formed. It supports the combustion of a taper, of charcoal, and of phosphorus, but not that of sulphur. It is readily absorbable by water, and possesses acid properties. Water saturated with this Gas forms the liquid nitrous Acid of commerce. The solution first becomes green, then blue, and finally orange. Dr. Thomson considers that this Acid is produced by the dry distillation of nitrate of lead; (q.) but Gay Lussac thinks that the Acid so obtained is the hyponitrous. (r.) Berzelius states that liquid nitrous Acid boils at 160° Fahrenheit, and he considers that it unites with bases to form Salts. (s.) But Gay Lussac states positively that it is so readily decomposed by contact with alkaline solutions, as to be quite incapable of forming a class of Salts.

*Subject. 6.—Pemptoxide of Nitrogen. Nitric Acid Gas.*

(458.) Liquid nitric Acid, which is a combination of this Gas with water, "seems to have been first obtained in a separate state by Raymond Lully, who was born at Majorca in 1285. He procured it by distilling a mixture of nitre and clay. Basil Valentine, who lived in the XVth century, describes the process minutely and

**Chemistry.** calls the Acid *water of nitre*. It was afterwards denominated *aqua fortis*, and *spirit of nitre*. The name *nitric Acid* was first given it in 1787 by the French Chemists." (Thomson.)

The direct synthetic formation of nitric Acid was first produced by Mr. Cavendish. It consists in passing a continuous current of electric sparks through a mixture of nitrogen and oxygen Gases. (t.) This Acid is, however, manufactured by distilling a mixture of sulphuric Acid and nitre. The Gaseous product is conducted into a vessel containing water, which being absorbed produces liquid nitric Acid. (u.) Nitric Acid Gas consists of five atoms of oxygen + one atom of nitrogen, but the strongest liquid Acid that can be obtained consists of the Acid Gas one atom + water one atom. It is frequently a matter of great convenience to know the quantity of real Acid contained in solutions of given density. We have, therefore, inserted Table VI. in Part V. by Dr. Ure, as the most extensive with which we are acquainted for that purpose. The Acid which Professor Thomson supposes to contain one atom of water to one atom of dry Nitric Acid Gas should have a Specific Gravity = 1.55, but that which he obtained equalled only 1.534. The Table, however, deduced from his experiments (v.) will be found Part V. No. VII.

The most stable combination of this Gas with water, forming a liquid Acid that may be distilled over, has Specific Gravity = 1.4237, and contains probably four atoms of water to one of real Acid. It boils at 248° Fahrenheit. The density at which nitric Acid most readily freezes, is, according to Mr. Cavendish, that of Specific Gravity 1.3, requiring a temperature of - 2° Fahrenheit. Two parts of Acid rapidly mixed with one part of water, both at 58° Fahrenheit, produce an elevation of temperature equal to 120° Fahrenheit. And fifty-eight parts by weight of Acid, Specific Gravity 1.50, added to forty-two parts of water, both at 60° Fahrenheit, are raised to 200° Fahrenheit. (w.)

The force with which this Acid retains its oxygen is not very considerable, so that combustible bodies readily decompose it: hence its effects on most of the metals. Thus also hydrogen decomposes it when heated, and produces a violent explosion. Essential oils produce an analogous effect, but the experiment is one requiring great caution.

This Acid is of great service in the Arts as a solvent of metals; and it has been employed partially in Medicine, but it does not appear to possess any very specific action on the human frame.

#### *Nitro-Muriatic Acid.*

(459.) For the sake of simplicity we retain the old name for this Acid, which is not, in fact, to be considered as even a proximate element, but only a compound frequently employed in Chemical researches. It is generally formed by mixing two parts of nitric Acid with one of hydrochloric Acid by weight; or even by one part of the former to four of the latter; a variation which abundantly proves either that the proportions are not very important, or that the rationale of the effects produced is not understood. The latter point has indeed been partially examined by Sir H. Davy. (x.) He "has rendered it probable that the peculiar properties of this Acid are owing to a mutual decomposition of the nitric and muriatic Acids, the oxygen of the former uniting

with the hydrogen of the latter, in consequence of which water, chlorine, and nitrous Acid are the results. For every 101 parts by weight of real nitric Acid (equivalent to 118 of hydronitric Acid) which are decomposed, 67 parts of chlorine, he calculates, are produced. According to this view, it is not correct to say that *aqua regia* (the old name of Nitro-Muriatic Acid) oxidates gold or platinum, since it merely causes their combination with chlorine. By long-continued and gentle heat Nitro-Muriatic Acid may be entirely deprived of chlorine, and it then loses its power of acting on gold or platinum.

"The Nitro-Muriatic Acid does not form with alkaline or other bases a distinct genus of Salts, entitled to the name of nitro-muriates; for when combined with an alkali, or an earth, the solution yields on evaporation a mixture of a muriate and a nitrate; and metallic bodies dissolved in it yield muriates only." Henry.

#### *Subsect. 7.—Ammonia.*

(460.) A. The liquid solution of Ammonia in water was known to the Alchemists, as it is mentioned in the writings of Basil Valentine and Raymond Lully. Dr. Black first pointed out the difference between its pure and its carbonated form, and Priestley first examined it as a Gas, calling it alkaline air. It is found in combination with Acids among volcanic products, and it is disengaged together with other Gases during the spontaneous decomposition of putrescent animal and vegetable matter.

(461.) B. Pure ammoniacal Gas is readily obtained for experiment by applying a lamp-heat to common *liquor Ammoniac* in a gas bottle with a bent tube. The Gas must be collected over mercury; or it may be produced by mixing equal parts of dry Sal ammoniac (hydrochlorate of Ammonia) with dry quick-lime, both in fine powder, and applying a lamp-heat, collecting the Gas as before. This Gas, which of course is the most pure form of the volatile alkali, consists of nitrogen combined with hydrogen in the proportion of one volume or atom of the former + three volumes or atoms of the latter condensed into two volumes. The synthetic union of these elements has not yet been effected, but the decomposition of Ammonia fully proves the accuracy of such a view of its constitution. It was analysed by A. Berthollet, and most satisfactorily by Dr. Henry. (r.) by detonation with oxygen. For the method of obtaining Ammonia for Medical and Commercial purposes, we must refer to Mr. Richard Phillips's excellent translation of the *Pharmacopœia*. (y.)

(462.) C. Ammoniacal Gas has a most pungent odour. It extinguishes flame, and when undiluted, cannot be respired. It is not sufficiently inflammable to burn in atmospheric air; but Dr. Henry found that he could ignite a small jet of it issuing into an atmosphere of oxygen Gas. It is lighter than atmospheric air, as will be seen from the table of Specific Gravity in Part V. Heat is capable of decomposing it when passed through a porcelain tube; so also is a current of electric sparks. Water will absorb 190 per cent. by volumes of this Gas. Its properties are decidedly alkaline, as it turns vegetable blues to green, and saturates Acids so as to form a class of Salts. At 50° Fahrenheit, and under a pressure of 6.5 atmospheres, Ammonia becomes a limpid colourless Liquid.

(463.) D. Oxygen has no immediate action on am

*Chemistry.* moniacal Gas but by explosion in Volta's eudiometer it combines with the hydrogen, setting free the nitrogen.

(464.) E. Scheele first applied chlorine to Gaseous Ammonia, and thus effected its decomposition; hydrochloric Acid and nitrogen resulting. Professor Thomson has availed himself of this process very successfully in the analysis of Sal Ammoniac. (2.) There can then be no combination of chlorine with Ammonia.

(465.) F. Unknown.

(466.) G. Iodine absorbs dry Ammoniacal Gas without decomposition: a brownish-red viscid substance results. But if iodine be added to the aqueous solution of Ammonia, decomposition takes place, a part of it unites with the hydrogen to produce hydriodic Acid, while another portion of the iodine unites with nitrogen, and forms a black powder of powerful detonating properties.

(467.) H. Unimportant, or in some cases none at all.

(468.) I. There is some sort of action between Ammonia and the metals, though its nature does not seem to be well understood. Of this we have the most important instance mentioned in Art. (426.) Thenard ascertained that when iron, copper, silver, gold, or platinum are enclosed in a heated porcelain tube, through which Ammonia is passed for its decomposition, they materially aid the process, and in the order above set down. The iron is rendered brittle, and the copper still more so; but the metals undergo no change of weight. Iron, however, decomposes a much greater quantity of the Gas than platinum does, and at a much lower temperature. (aa.)

(469.) K. The qualities of Ammonia are so decidedly alkaline, that it never performs the part of an Acid with any base; but it acts extensively as a base, forming numerous and important Salts. With carbonic Acid it unites in three different proportions.

(470.) L. Ammoniacal Salts are readily recognised by the odour they emit when rubbed in a mortar with a small quantity of quick-lime: when the Ammoniacal Gas thus evolved is very minute in quantity, it is rendered very apparent by holding over the powder a glass rod which has been dipped in hydrochloric Acid. White fumes are then seen, consisting of hydrochlorate of Ammonia.

(471.) M. Preparations of Ammonia are of considerable service in Medicine. In small quantities they act as stimulant, rubefacient, and antacid: in larger quantities they are emetic.

#### Subsect. 8.—Cyanogen. Bicarburé of Nitrogen.

(472.) Cyanogen Gas derives its name from *κυανός*, blue, and *γενεσθαι*, to generate, because of its forming the essential part of Prussian blue. It owes its name and rank, as a proximate element, to the researches of Gay Lussac, made in 1815. (bb.) Scheele had, however, accidentally produced the same substance long before.

To obtain this Gas, the cyanuret of mercury (*olim* Prussiate) is to be carefully dried, and then exposed in a small retort to the heat of a spirit-lamp. Gaseous Cyanogen is evolved, and the mercury is sublimed. This Gas is without colour, but has a pungent odour. It is a limpid Liquid, at 45° Fahrenheit, under a pressure of 3.6 atmospheres. It extinguishes burning bodies, and is itself combustible, burning with a beautiful purple flame. At 60° Fahrenheit, water absorbs 4.5, and alcohol twenty-three times its volume of this Gas. This Gas has a strong affinity for the metals,

thus producing metallic cyanurets; but its affinity for oxides is very slight. It does not form stable compounds with bases; and though its aqueous solution reddens litmus-paper, that effect is due to the formation of other Acids by mutual decomposition, so that it cannot be considered as an Acid. (cc.) Cyanogen contains nitrogen Gas one atom or volume + carbon vapour two atoms or volumes condensed into one volume. It may be analysed by detonation with oxygen in Volta's eudiometer.

The compounds of Cyanogen are highly interesting, forming a class of important proximate elements. The following is a synoptic view of their constitution

Cyanic Acid..... = oxygen one atom + Cyanogen one atom.

Of this Acid there seem to be two varieties, having the same ultimate constitution.

Hydrocyanic Acid..... = hydrogen one atom + Cyanogen one atom.

Chlorocyanic Acid..... = chlorine one atom + Cyanogen one atom.

Iodide of Cyanogen..... = iodine one atom + Cyanogen one atom.

Ferro-hydrocyanic Acid. = iron one atom + hydrogen two atoms + Cyanogen three atoms;

or = hydrocyanic Acid two atoms + cyanuret of iron one atom.

Sulpho-hydrocyanic Acid = sulphur two atoms + hydrogen one atom + Cyanogen one atom;

or = bisulphuret of Cyanogen one atom + hydrogen one atom.

Selenio-hydrocyanic Acid = selenion ? atoms + hydrogen ? atoms + Cyanogen ? atoms.

These compounds we shall briefly notice in succession.

#### Cyanic Acid.

(473.) That there should be two varieties of Cyanic Acid having the same atomic constitution is a singular fact; but is not, according to the present belief, without parallel.

*Cyanic Acid of M. Wöhler.*—This Chemist found that when alkaline solutions are saturated with cyanogen Gas, a decomposition takes place, and that Hydrocyanic and Cyanic Acids are both produced, so that the action of alkaline solutions on Cyanogen is similar to that upon iodine, chlorine, or sulphur.

The cyanate of potassa is obtained by exposing to a low red-heat a mixture of equal weights of ferro-hydrocyanate of potassa and finely-powdered peroxide of manganese. The mass that has been heated is then to be boiled in alcohol of eighty-six per cent. strength; and as the solution cools, cyanate of potassa is deposited in small laminary crystals. This Acid forms a soluble Salt with baryta, and insoluble Salts with the oxides of lead, mercury, and silver. (dd.)

*Cyanic Acid of M. Liebig.*—This Acid was obtained from the fulminating mercury of Mr. Howard, a compound to be hereafter described. (See *Mercury*.) This substance seems to consist of a true cyanate of mercury. Similar Salts may be formed of silver and other metals; but the Cyanic Acid has not hitherto been obtained from them in a separate state; for in attempting their decomposition by alkalis, double Salts are formed, which also possess detonating properties. (ee.)

(474.) Scheele discovered this Acid in 1782; and Berthollet ascertained its ultimate elements to be carbon, nitrogen, and hydrogen. Gay Lussac, by discovering the true nature of cyanogen, showed it to be the base of the Acid, and hydrogen the acidifying principle.

Hydrocyanic Acid is obtained by heating three parts of cyanuret of mercury with two parts by weight of concentrated hydrochloric Acid in a glass retort. A vapour of water, hydrochloric Acid, and Hydrocyanic Acid rises, and is purified from the hydrochloric Acid by being suffered to pass through a narrow tube, containing fragments of marble, which take up the latter Acid. It is next conveyed through dry chloride of calcium, and condensed in a vessel surrounded with ice.

Vauquelin, however, recommends in preference, that a narrow horizontal tube should be filled with fragments of the mercurial cyanuret; and that then a current of hydrosulphuric Acid Gas should be slowly admitted. The instant that Gas comes in contact with the cyanuret, double decomposition ensues; Hydrocyanic Acid and the black sulphuret of mercury being generated. The progress of the hydrosulphuric Acid along the tube may be distinctly traced by the change of colour, and the experiment may be terminated so soon as the whole of the cyanuret has become black. The Hydrocyanic Acid is then to be expelled by a gentle heat, and collected in a cool receiver.

For Medicinal purposes it is prepared at Apothecaries' Hall, by mixing in a retort one part of cyanuret of mercury, one part of hydrochloric Acid, (Specific Gravity 1.15,) and six parts of water. This is distilled at a gentle heat, giving an Acid of Specific Gravity 0.995. (ff)

Pure condensed Hydrocyanic Acid is a limpid Fluid of Specific Gravity 0.7058, at 45° Fahrenheit. It has a strong odour of the peach blossom, and the vapour, when breathed even with much atmospheric air, produces giddiness and headach. When diluted, it has the taste of bitter almonds. This Acid is extremely volatile, and boils at 79° Fahrenheit: at zero it congeals. Even when closely confined, it most readily undergoes spontaneous decomposition, so that it cannot well be preserved undiluted many days. During decomposition it assumes a brownish tint. It reddens litmus-paper feebly, and combines with bases to form Salts; but it is so feeble as not to decompose the carbonates, nor can it be made to neutralize potassa.

By Voltaic electricity it is decomposed, the hydrogen appearing at the negative pole, the cyanogen at the positive one. It is also partially decomposed by being passed through a red-hot porcelain tube. With oxygen Gas it detonates in Volta's eudiometer. It is best analysed by potassia, as in Gay Lussac's experiments.

Free Hydrocyanic Acid is readily recognised by its odour. A fluid which is supposed to contain it may be agitated with finely-powdered oxide of mercury. By double decomposition water and cyanuret of mercury are produced, and on evaporating the filtered solution, small crystals of the cyanuret are obtained.

Dr. Ure has given the following process for estimating the strength of any solution of Hydrocyanic Acid met with in commerce. "To 100 grains of the Liquid contained in a phial, let small given quantities of the finely-powdered peroxide of mercury successively be added, until it ceases to be dissolved. The weight of peroxide

so dissolved, divided by four, gives the quantity of real Hydrocyanic Acid present." (gg.)

The distilled water of the *Prunus Lauro-cerasus* owes its odour and poisonous properties to this Acid; it exists also in the bitter almond, and in the bird-cherry.

The Hydrocyanic Acid, when pure, is so violent a poison, that one drop may be fatal. In a diluted state it is now given Medicinally with much success, chiefly to allay irritation in pulmonic complaints. (hh.)

#### Chlorocyanic Acid.

(475.) If chlorine Gas be passed through an aqueous solution of hydrocyanic Acid, until the Liquid acquires bleaching properties, and then the redundant chlorine be removed by agitation with mercury, two Acids remain, the hydrochloric, and the Chlorocarbonic, first called the Oxyprussic by Berthollet. This Acid is at present little known, and seems scarcely to have been obtained in a separate state. Its composition, as stated by M. Gay Lussac, has been already mentioned.

#### Iodide of Cyanogen; or Cyanuret of Iodine.

(476.) Such are the names given to a compound of these elements not possessed of acid properties. It was discovered in 1824 by M. Serullas, and may be obtained by mixing two parts of cyanuret of mercury with one of Iodine, both quite dry, in a glass mortar. This mixture is to be put into a wide-mouthed phial. On the first application of heat, vapours of Iodine appear, but so soon as the Cyanuret undergoes decomposition, white fumes are seen, which will condense on the sides of a cool glass receiver in flocculi like cotton wool.

This Iodide of Cyanogen has a caustic taste and acrid odour, exciting tears. It is very volatile, and bears a heat of more than 212° Fahrenheit, without decomposition, but its elements are disunited by a red-heat. It is soluble in water. (ii.)

*Ferro-hydrocyanic Acid. Ferruretted Chyazic Acid. (Porrett.) Ferro-cyanic Acid. Acide Hydro-cyanique ferrurée. (Thenard.)*

(477.) We are disposed to prefer the name standing first among these synonyms, as best expressing the constitution of this Acid; viz. that iron and hydrogen both simultaneously combine in forming an acid compound, having cyanogen for a base. Or it might possibly be said that iron in combination exerts a modifying agency upon what would otherwise be Hydrocyanic Acid. Mr. Porrett, to whom, with Messrs. Wilson and Rupert Kirk, we are much indebted for able researches into the nature of these interesting compounds, proposed the name of Chyazic Acid, forming the word from the initial parts of its elements, carbon, hydrogen, and azote. We object to the name of Ferro-cyanic Acid, because it would seem to express the nature of the substance, and yet omits an important element. By some it is considered that hydrogen acts as the acidifying principle upon a sort of double radical consisting of both cyanogen and cyanuret of iron.

The following are two processes recommended by Mr. Porrett for obtaining this Acid. 1. Let 58 grains of crystallized tartaric Acid be dissolved in alcohol, and



**Chemistry.** let this Liquid be mixed with 50 grains of Ferro-hydrocyanate of potassa, (prussiate of potash,) dissolved in the smallest possible quantity of hot water. The bitartrate of potassa is precipitated, and the clear remaining solution, on being allowed to evaporate spontaneously, gradually deposits small yellow cubic crystals of Ferro-hydrocyanic Acid.

2. Let sulphuric Acid be mixed with Ferro-hydrocyanate of baryta, in the proportion of 2.53 grains of real sulphuric Acid to every ten grains of the Salt. The insoluble sulphate of baryta is precipitated, and the Ferro-hydrocyanic Acid remains in solution.

This Acid is not volatile, neither in small quantity is it a poison. By exposure to light it gradually decomposes, forming Hydrocyanic Acid and Prussian blue. But it is a more stable compound than Hydrocyanic Acid is. It reddens vegetable blues, and neutralizes alkalis, displacing also the carbonic and acetic Acids. It is now pretty generally admitted that Ferro-hydrocyanic Acid contains no oxygen, and that Prussian blue is a Ferro-hydrocyanate of the peroxide of iron. For the very elaborate Memoirs that have appeared on this substance see the reference (kk.) The persalts of iron are the most delicate tests of the presence of this Acid.

*Sulpho-hydrocyanic Acid. Sulphocyanic Acid, or Sulphuretted Chyazid Acid.*

(478.) The last of these synonyms is the name given to an Acid by its discoverer, Mr. Porrett, in 1828. It is obtained by the following process. Let equal weights of powdered Ferro-hydrocyanate of potassa and Flowers of sulphur be well mixed, and exposed in a small flask to a heat sufficient to keep the sulphur in a liquid state for several hours. When the mass has become cold, let it be pulverized and digested in water, so as to take up every thing soluble. Filter the Liquid, and drop in a sufficient quantity of potassa to precipitate any iron that may be held in solution. This Liquid is a solution of Sulpho-hydrocyanate of potassa. Sulphuric Acid is then to be added in sufficient quantity to engage the alkali, and the mixture is to be distilled. The Liquid so obtained is a solution of Sulpho-hydrocyanic Acid in water.

The Acid thus proposed is a transparent Liquid, having sometimes a light pink colour. The greatest density that Mr. Porrett could obtain was 1.022. It boiled at 216.5° Fahrenheit, and at 54° 5 Fahrenheit crystallized in six-sided prisms. It reddens litmus-paper, and forms Salts with alkaline bases. Its presence is readily detected by its giving a white precipitate with a Salt of the peroxide of copper, and a deep blood-red one with any persalt of iron. At present we are under some uncertainty about the mode of combination among the Elements of this Acid. It is supposed by some to be a hydracid, having bisulphuret of cyanogen for its radical. (ll.)

*Selenio-hydrocyanic Acid.*

(479.) The existence of an Acid to which this name will apply, has been detected by M. Berzelius, but at present it has been little examined.

References to § 8.

(a.) Berzelius, *An. Phil.* vol. ii. p. 276; Miers, *An. Phil.* vol. iii. p. 364, and vol. iv. pp. 180, 260; Seebeck, *An. de Ch.* vol. lxvi. p. 191; Tromsdorff, Berzelius, and Pontin, *Bibl. Brit.* Nos. 323, 324; Gay Lussac and

Thenard, *Recherches*, vol. i. p. 52; Davy, *Phil. Trans.* Part II. 1810. (b.) *An. de Ch.* vol. lxxxv. (c.) *Phil. Trans.* 1813. (d.) Porret, Wilson, and Kirk, *Nich. Jour.* vol. xxxiv. p. 180. (e.) *Manch. Mem.* vol. v. p. 583; and *Manch. Mem.* N. S. vol. i. p. 257. (f.) *An. de Ch.* vol. xxiv. p. 78. (g.) *Phil. Mag.* vol. iii. p. 171. (h.) *Nich. Jour.* 8vo. vol. iv. p. 210. (i.) *Elem. Chem.* vol. i. p. 293. (j.) *Phil. Trans.* 1807 (k.) Priestley, *On Airs*, vol. ii. p. 54. (l.) *Jour. de Phys.* vol. xlii. p. 323. (m.) Sadler, *Nich. Jour.* vol. xv. p. 286. (n.) Henry, *Chem. Ed.* 10. vol. i. p. 313. (o.) *An. de Ch. et Phys.* vol. i. p. 400. (p.) Thomson, *An.* vol. ix. and x. (q.) *First Principles*, vol. i. p. 120. (r.) *An. de Ch. et Phys.* vol. i. p. 406. (s.) *An. de Ch.* vol. xiii. p. 10. (t.) *Phil. Trans.* vol. lxxxv. (u.) Phillip's *Transl. of the Pharmacopœia*, p. 28; and Percival, *Trans. Irish Acad.* vol. iv. p. 37. (v.) *First Principles*, vol. i. p. 113. (w.) Ure, *Journal of Science*, vol. iv. p. 208. (x.) *Journal of Science*, &c. vol. i. p. 67; Henry, *Phil. Trans.* 1809; and *An. Philos.* N. S. vol. viii. p. 341. (y.) *Ed.* 1824, p. 37. (z.) *First Principles*, vol. i. p. 129. (aa.) *An. de Ch.* vol. lxxxv. p. 61. (bb.) *An. de Ch.* vol. xcv. (cc.) Vauquelin, *An. de Ch. et Phys.* vol. ix. (dd.) Wöhler, *An. de Ch. et Phys.* vol. xx. and xxvii. (ee.) Howard, *Phil. Trans.* 1800; Liebig, *An. de Ch. et Phys.* vol. xxiv.; Liebig and Gay Lussac, *An. de Ch. et Phys.* vol. xxv. (ff.) Brande, *Manual*, vol. i. p. 140. (gg.) *Jour. of Science*, vol. xiii. p. 312. (hh.) *An. de Ch.* vol. lxvii. p. 128; vol. xc. p. 136; Viborg, *Act. Nov. R. S. Med. Hafn.* vol. xi.; Thomson, *Lond. Med. and Phys. Jour.* Feb. 1822; Magendie *sur le Prép. et Emploi de plusieurs nov. Médicaments*, Ed. 5. p. 108. (ii.) Serullas, *An. de Ch. et Phys.* vol. xxvii. (kk.) Scheele, *Chem. Ess.* p. 391; Porrett, &c. *Phil. Trans.* 1814 and 1815; Berzelius, *An. de Ch. et Phys.* vol. xv.; Robiquet, *An. de Ch. et Phys.* vol. xvii.; *An. de Ch. et Phys.* vol. xxii. p. 320. (ll.) Porrett, &c. *Phil. Trans.* 1814, 1815; Vogel, &c. *An. de Ch. et Phys.* vol. xvi. p. 23.

## CHAPTER IV.

### General Remarks on the Metals.

(480.) It may possibly conduce to a clear understanding of the properties of this most interesting class of bodies, if we take a brief survey of the various artificial divisions or systems of classification which have been proposed for them. Seven Metals only were known to the Ancients, gold, silver, iron, copper, lead, tin, and mercury. These were divided into perfect and imperfect; gold and silver being considered the perfect metals, from their superiority over the others in ductility, tenacity, and probably in a great measure from their not being liable to rust or decay. The XVIIIth century, however, as it produced that system of Chemical analysis which we now regard as accurate, gave birth to several other pure Metals; the Chemical elements obtained in separating the constituent parts of compound bodies.

The next arrangement that we feel disposed to mention is that of Fourcroy, in many respects a convenient classification to be borne in mind. He divides the Metals into five Orders.

## Chemistry.

Order 1.—*Brittle and Acidifiable.*

Arsenic.	Molybdenum.
Tungsten.	Chromium.

Order 2.—*Brittle and simply Oxidable.*

Titanium.	Bismuth.
Uranium.	Antimony.
Cobalt.	Tellurium.
Manganese.	

Order 3.—*Oxidable and imperfectly Ductile.*

Mercury.	Zinc.
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Order 4.—*Easily Oxidable and Ductile.*

Tin.	Iron.
Lead.	Copper

Order 5.—*Difficult of Oxidation and very Ductile.*

Silver.	Palladium.
Gold.	Platinum

Another arrangement was proposed by Dr. Thomson in the 3d Edition of his *Chemistry*, and is employed by L. r. Henry. Here there are four Classes.

Class 1.—*Malleable Metals.*

Gold	Osmium.
Platinum.	Copper.
Silver.	Iron.
Mercury.	Nickel
Palladium.	Tin.
Rhodium.	Lead.
Iridium.	Zinc

Class 2.—*Brittle and easily fused.*

Bismuth.	Tellurium.
Antimony.	Arsenic.

Class 3.—*Brittle and difficult of Fusion.*

Cobalt.	Molybdenum.
Manganese	Uranium.
Chromium.	Tungsten.

Class 4.—*Refractory Metals.*

Titanium.
Columbium.
Cerium.

In the most recent edition of Dr. Thomson's Work, arsenic, tellurium, and osmium are removed from the rank of Metals, and fall in with his "acidifiable combustibles," phosphorus, sulphur, &c. Then come 31 Metals, which form "*alkalis* or *bases* capable of constituting neutral Salts with Acids, by uniting with the supporters of combustion." These are arranged under five Families.

*Family 1.* contains those bodies which, "when combined with oxygen, possess the alkaline properties in the greatest perfection. They all convert vegetable blues to green, and are all soluble in water, with the exception of magnesia," which is so to only a very slight extent. Here we have the bases of the alkalis and alkaline earths of former Chemists

1. Potassium.	5. Borium
2. Sodium.	6. Strontium.
3. Lithium.	7. Magnesium.
4. Calcium.	

*Family 2.*—The compounds which the elements contained in this Family "form with oxygen are white, and these oxides form colourless solutions in Acids; it has hitherto been impossible to reduce them in any quantity to the Metallic state. They are insoluble in water, and produce no alteration in the colour of vegetable blues. On that account they were formerly distinguished in Chemistry by the name of *earths proper*."

1. Yttrium.	4. Zirconium.
2. Glucinum.	5. Thorium.
3. Aluminium.	

*Family 3.*—The Metals in this Family "are distinguished by two properties: 1. Their oxides cannot be reduced to the Metallic state by the most violent heat that can be applied. 2. When dissolved in an Acid they cannot be precipitated in the Metallic state by plunging into the solution a rod of any other Metal."

1. Iron.	4. Manganese.
2. Nickel.	5. Cerium.
3. Cobalt.	6. Uranium.

*Family 4.*—The substances belonging to this Family "are precipitated from their solutions in Acids, in the Metallic state, in the order of the following Table. Zinc precipitating all the others; but not being itself precipitated by any of them. Lead precipitates all except zinc and cadmium. Tin all except zinc and lead. Copper precipitates only bismuth, mercury, and silver. Silver is precipitated by all the rest, but does not itself precipitate any of the others."

1. Zinc.	5. Copper.
2. Cadmium.	6. Bismuth.
3. Lead.	7. Mercury.
4. Tin.	8. Silver.

*Family 5.*—In this Family, consisting of five Metals, "they all require a strong heat to fuse them; they are all insoluble in nitric Acid, and their oxides are reducible to the Metallic state by the application of heat alone."

1. Gold.	4. Rhodium.
2. Platinum.	5. Iridium.
3. Palladium.	

The remaining Metals which in Dr. Thomson's system do not enter any of these Families constitute a genus apart. They are described as "bodies producing by their union with the supporters of combustion imperfect Acids, or substances intermediate between Acids and alkalis."

1. Antimony.	4. Tungsten.
2. Chromium.	5. Columbium.
3. Molybdenum.	6. Titanium.

(481.) We now proceed to that classification of the Metals which we have adopted in this Essay. It is almost identical with that made use of by M. Thenard in former editions of his admirable *Traité de Chimie*; but it differs in that we have already treated of silicon by removing it from the class of Metals: a measure justified by the opinions of Thomson and Berzelius. In the last edition of M. Thenard's Work (the fifth) he has placed *silicon* and *zirconium* in a division by themselves as intermediate between the substances of our third Chapter and the Metals. Berzelius has recently ascertained that *thorina*, which he had considered a peculiar earth, is a phosphate of yttria. The name, however, still remains in our Synopsis, as the same

Chemist has discovered another earth which he deems a simple substance, and from a similarity of properties proposes that it should occupy the vacant name. The following forty Metals then will stand in six classes, chiefly dependent for their distinction upon the degree of their affinity for oxygen.

(482.) *Class 1.*—Those Metals which have not yet been actually obtained by reduction from their oxides, and exhibited in a pure state, though considered Metals on sufficiently strong analogies.

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|---------------|---------------|
| 1. Zirconium. | 4. Yttrium.   |
| 2. Thorium?   | 5. Glycynum.  |
| 3. Aluminium. | 6. Magnesium. |

(483.) *Class 2.*—Metals which instantly decompose water at ordinary temperatures; combine with oxygen Gas at the same temperature, or by the aid of a slight heat; and whose oxides are reducible by Electricity, or by certain very combustible bodies; but cannot be reduced by heat alone.

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|---------------|---------------|
| 1. Potassium. | 4. Barium.    |
| 2. Sodium.    | 5. Strontium. |
| 3. Lithium.   | 6. Calcium.   |

(484.) *Class 3.*—Metals which are capable of decomposing water but only at a red heat; which combine with oxygen at some temperature; and whose oxides are reducible by electricity, and by different combustible bodies, though not reducible by any heat alone however violent.

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|---------------|-------------|
| 1. Manganese. | 4. Tin.     |
| 2. Zinc.      | 5. Cadmium. |
| 3. Iron.      |             |

(485.) *Class 4.*—The Metals of this section are incapable of decomposing water at any temperature; they combine with oxygen upon some elevation of temperature; their oxides are reducible by Electricity, and by different combustible bodies, but not reducible by heat alone.

The Metals of this section are again subdivided into first, those which are capable of becoming Acids; and secondly, those which form oxides only.

*Acidifiable.*

- |                |               |
|----------------|---------------|
| 1. Arsenic.    | 4. Tungsten.  |
| 2. Molybdenum. | 5. Columbium. |
| 3. Chromium.   |               |

*Not Acidifiable.*

- |              |               |
|--------------|---------------|
| 1. Antimony. | 6. Bismuth.   |
| 2. Uranium.  | 7. Copper.    |
| 3. Cerium.   | 8. Tellurium. |
| 4. Cobalt.   | 9. Nickel.    |
| 5. Titanium. | 10. Lead.     |

M. Thenard suggests that some of these, especially antimony, titanium, and tellurium, have a claim to be considered acidifiable Metals.

(486.) *Class 5.*—Metals which do not decompose water at any temperature, but which combine with oxygen at some temperature or other, and whose oxides are reducible by heat alone.

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|-------------|------------|
| 1. Mercury. | 2. Osmium. |
|-------------|------------|

(487.) *Class 6.*—Those Metals which do not decompose water at any temperature; do not combine with oxygen at any temperature; and whose oxides formed indirectly are easily reducible by heat alone.

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|---------------|--------------|
| 1. Silver.    | 4. Platinum. |
| 2. Palladium. | 5. Gold.     |
| 3. Rhodium.   | 6. Iridium.  |

METALS. CLASS I.

*Sect. I.—Zirconium.*

(488.) Of this Metal, the oxide of which forms the earth Zirconia, (see subject. 1.) we have few details; and for the slender knowledge which we possess, we are entirely indebted to Sir H. Davy. He submitted the earth Zirconia, in contact with potassium and mercury, to the action of Voltaic Electricity, and obtained results which showed that some portion of the earth had undergone decomposition; the metallic amalgam being capable of decomposing water, and the Zircon earth being found as a product after that decomposition. Davy also applied potassium to Zirconia at a white heat: the potassium was for the most part converted into potash, and dark particles, which, when examined with a magnifying glass, appeared metallic in some parts, and chocolate brown in others, were found diffused through the potash and the undecomposed earth. (a.)

*Subsect. 1.—Zirconia.*

(489.) A. By analyzing Zircon, a mineral found in the Island of Ceylon, Klaproth, in the year 1789, discovered a new earth, which he named Zirconia. (b.) In 1795 he published his Analysis of the Hyacinth, another mineral from the same island, and found in this also a considerable proportion of the same earth. (c.) Morveau then, in 1796, examined the Hyacinths from Expailly in France, in which he also found Zirconia. (d.) Vauquelin has also given some Memoirs on this subject; (e.) and still more recently, M. Chevreul. (f.) MM. Dubois and Silveira have proposed an improved process for obtaining this earth. (g.)

(490.) B. This process consists in submitting the Zircons, reduced to a fine powder, and mixed with two parts of pure potash, to a red heat for an hour in a silver crucible. The mass is then treated with distilled water filtered and thoroughly washed. The residuum upon the filter consists of Zirconia, silica, with some potash, and oxide of iron. It is then dissolved in hydrochloric Acid, and evaporated to dryness, for the purpose of separating the silica. Let the muriate of Zirconia and iron be redissolved in water; and to separate a little Zirconia which will adhere to the silica, wash the latter with a little weak hydrochloric Acid, and add this to the solution. After filtering the Liquid, let the Zirconia and iron be precipitated by pure ammonia; wash the precipitate well, and treat it with oxalic Acid, boiling them well together; by this the oxide of iron will be dissolved out, and an insoluble oxalate of Zirconia will be formed. Filter and wash the oxalate until no iron can be detected in the washing. The oxalate of Zirconia well washed and dried is of an opaline colour, and may be decomposed by heat in a platinum crucible.

(491.) C. Zirconia is a fine, white powder without taste or smell, but feeling gritty between the fingers; infusible save by the Gas blowpipe. It is insoluble in water, but has a strong affinity for that Liquid. When slowly dried, after being precipitated from a solution, it retains about one-third its weight of water, and assumes

Chemistry. a yellow colour, with some degree of transparency, which gives it the appearance of gum arabic.

(492.) D. E. F. G. none, or unnoticed.

(493.) H. Zirconia does not combine with these nonmetallic substances.

(494.) I. Neither has it any other known action with the Metals, save that which has been already noticed in sect. 1.

(495.) Zirconia is insoluble in liquid caustic alkalis, neither does it combine with them by means of heat; but it is soluble in the liquid alkaline carbonates. It fuses with silica and alumina by fusion, as also with some of the metallic oxides.

After precipitated Zirconia has been exposed to a red heat, or even well dried, it scarcely can be said to be soluble in Acids, but when newly precipitated, and still moist, it dissolves readily.

The greater part of the Salts of Zirconia are insoluble in water; "such are the sulphate, sulphite, phosphate, fluat, borate, carbonate, selenate, oxalate, tartrate, citrate, saccharate, and gallate. But the hydrochlorate, nitrate, acetate, benzoate, and malate are soluble." (Thomson.) The Salts of Zirconia have a harsh, astringent, disagreeable taste, similar to that of some of the metallic Salts. (c.)

(496.) L. Sulphuric Acid added to a neutral solution of Zirconia, if not too dilute, produces a white precipitate. Carbonate of ammonia produces also a white precipitate, soluble in excess of the reagent, by which Zirconia is distinguished from alumina. Oxalate of ammonia and tartrate of potash also produce white precipitates of the insoluble oxalate and tartrate. Hydrosulphuret of potash produces no precipitate, but infusion of galls will give a white one

(497.) M. None.

#### References to § I.

(a.) Davy, *Elements*, p. 360. (b.) *Jour. de Phys.* vol. xxxvi. p. 180. (c.) Klaproth, *Beitrag*, vol. i. p. 231. (d.) *An. de Ch.* vol. xxi. p. 72. (e.) Vauquelin, *An. de Ch.* vol. xxix. p. 158, and *Jour. des Mines*, No. 5. p. 97. (f.) Chevreul, *An. de Ch. et Ph.* vol. xiii. p. 245. (g.) *An. de Ch. et Ph.* vol. xiv. p. 110.

### Sect. II.—Yttrium.

(498.) The name Yttrium has been assigned to the supposed base of the earth yttria. Of the existence of this Metal experiments similar to those made upon zirconia seemed to afford to Sir H. Davy sufficient proof. According to this opinion, which is generally received, yttria is a metallic oxide. Its properties will fall under the following subsection.

#### Subsect. 1.—Yttria.

(499.) A. "Some time before 1788, Captain Arhenius discovered, in the quarry of Ytterby, in Sweden, a peculiar mineral." This mineral is now called Gadolinite, after its first analyst. It was first described by Gayer in *Crell's Annals* for 1788. Professor Gadolin analyzed this mineral in 1794, (a.) and found it to contain a new earth; but though his analysis was published in the *Stockholm Transactions* for 1794, and in *Crell's Annals* for 1796, it was some time before it attracted the attention of Chemical mineralogists. The conclusions of Gadolin were confirmed by Ekeberg in 1797,

who gave to the new earth the name of Yttria. (b.) These researches were still further extended by Vauquelin in 1800; (c.) and likewise by Klaproth about the same time: (d.) Ekeberg also published a new dissertation on the subject in the *Swedish Transactions* for 1802. (e.) Since that time Yttria has been repeatedly examined, by Berzelius, who has shown (f.) that the earth examined by Ekeberg and Gadolin was not pure. He has himself succeeded in separating it from most of the cerium with which it was contaminated, and has described its properties. (g.)

Yttria has as yet only been found in the Gadolinite above mentioned; in yttrio-tantalite another Swedish mineral, where it is combined with tantalum; and in combination with phosphoric Acid, by which it produced the earth to which Berzelius had given the name of Thorina, supposing it to be a new proximate element.

(500.) B. Yttria is obtained from yttrio-tantalite, the more plentiful mineral, by the following process. The pulverized mineral is to be dissolved in nitro-muriatic Acid. The solution is then to be highly concentrated by evaporation, then filtered and diluted with water. Thus the silica is in a great measure got rid of. The filtered Liquid is to be evaporated to dryness, and the residue submitted for some time to a red heat in a close vessel, and then redissolved in water and filtered. To the clear solution let ammonia be added, and a mixture of Yttria and oxide of cerium is precipitated. Heat this powder to redness, dissolve in nitric Acid, and again evaporate to dryness, to get rid of the excess of Acid. Add 150 parts of water, and put into the Liquid crystals of sulphate of potash. The crystals gradually dissolve, and after some hours a white precipitate of oxide of cerium appears. The latter process is to be repeated to be certain of having got rid of all the oxide of cerium. The Yttria may be precipitated from the filtered liquor by pure ammonia, and after being well washed is to be heated to redness. (f.)

(501.) C. Yttria produces neither taste nor smell, nor has it any effect on vegetable colours. It is heavier than the other earths, its Specific Gravity being 4.84, according to Ekeberg. It is insoluble in water, but absorbs and strongly retains that fluid.

(502.) D. E. F. G. It is not probable that Yttria has any mutual action with these substances.

(503.) H. Neither is it likely that it would unite with any substance in this division, as Klaproth could not produce a combination with sulphur.

(504.) K. Yttria is not soluble in the liquid caustic alkalis, nor is it dissolved by excess after having been precipitated by them from its solutions. In this it differs from glycyna. Like glycyna, it is soluble in carbonate of ammonia, but requires five or six times the quantity of that menstruum.

Yttria combines with the Acids, exerting considerable strength of affinity, as it precipitates alumina, zirconia, and glycyna from their solutions. It is itself precipitated by the alkalis and alkaline earth. Its Salts, when quite pure, are colourless, and have a sweet taste. Those which are soluble, the sulphate, nitrate, hydrochlorate, and acetate, are crystallizable: they are always acidulous, the chromate excepted: but even with this excess of Acid, they refuse to dissolve any additional portion of the earth. The insoluble Salts, viz. the phosphate, arseniate, carbonate, seleniate, oxalate, tartrate, succinate, and citrate, are, however, neutral.

(505.) L. Yttria is precipitated by prussiate of pot-

**Chemistry.** ash of a greyish colour. Also in grey flocculi by infusion or tincture of galls, but very slightly by pure gallic Acid. Its saline solutions are not affected by hydrosulphuric Acid, nor by sulphuret of ammonia. It is also precipitated by phosphate of soda, carbonate of soda, and oxalate of ammonia.

(506.) M. None.

References to § 2.

(a.) Gadolin, *Crell's Annals*, 1796, p. 313. (b.) *Crell's Annals*, 1799, vol. ii. p. 63. (c.) Vauquelin, *An. de Ch.* vol. xxi. p. 143. (d.) Klaproth, *Beil.* vol. iii. p. 52; *An. de Ch.* vol. xxxvii. p. 86. (e.) Ekeberg, *Kongl. Vetenskaps Acad. nya Handlingar*, 1802, p. 86; or *Jour. de Ch.* vol. iii. p. 78. (f.) *Afhandlingar*, &c., vol. iv. p. 217—235; or *An. Phil.* vol. iii. p. 359; or *An. de Ch. et Ph.* vol. iii. p. 26—33. (g.) Thomson, *Chem.* vol. i. p. 369.

Sect. III.—*Glycynum*.

(507.) For the existence of this Metal we have the same evidence as is exhibited in the case of zirconium, and for this knowledge we are also indebted to Sir H. Davy. The process he employed was the same as he made use of for zirconium. (488.) The oxide of Glycynum forms the earth glycyna, which we shall describe in the following subsection.

Subsect. 1.—*Glycyna*.

(508.) A. In the year 1798, the Abbé Haüy requested Vauquelin to analyze the emerald and beryl, in consequence of an inference which he had deduced from their crystalline forms, that the two minerals contained the same chemical elements. Haüy's conjecture was confirmed by the analysis, and Vauquelin was rewarded by the discovery of a new earth, to which the name of Glycynum was given, in consequence of the sweet taste of its Salts. (*γλυκύς*.) Vauquelin's experiments (a) have been repeated by Klaproth, (b.) and Ekeberg, (c.) and Berzelius. Glycyna is found in the emerald, beryl, and enclase. It has been usual to write this word Glucina, but the ordinary laws of derivation from its Greek source require that it should be Glycyna, or even in still greater strictness Glycyna.

(509.) B. To obtain this earth, the mineral containing it is to be finely powdered, and then fused with thrice its weight of potash. To the fused mass add a little water, and then dissolve in hydrochloric Acid; evaporate the solution to dryness. Add then abundance of water, and filter out the silica. The muriates of Glycyna, &c. pass through in solution. Precipitate the earths by carbonate of potash. Wash the precipitate well, and dissolve it in sulphuric Acid. Then to this solution add a solution of sulphate of potash; concentrate by evaporation, and leave the Liquid to crystallize. Crystals of alum are thus removed. When as many of these have been obtained as is possible, add carbonate of ammonia in excess, filter and boil the Liquid for some time. The Glycyna gradually subsides in the form of a white powder.

(510.) C. Glycyna is a soft, white powder, infusible save by the Gas blowpipe, causing neither taste nor smell, but adhering to the tongue. It does not affect vegetable colours, is insoluble in water, but forms a paste with that Liquid.

(511.) D. E. F. G. These have no action on Glycyna.

(512.) H. With the simple combustibles it does not combine.

(513.) I. Nor yet with the metals.

(514.) K. Glycyna is soluble in solutions of the fixed alkalis like alumina. It agrees with yttria in being insoluble in ammonia, but soluble in its carbonates, though in a much greater degree. It is soluble also in the other alkaline carbonates. Glycyna readily combines with all the Acids, and even the hydrosulphuric. Its Salts are for the most part soluble in water, but the greater part are not crystallizable. The carbonate, phosphate, selenate, and succinate are insoluble.

(515.) L. Prussiate of potassa gives a white, and infusion of galls a yellow, precipitate when added to the solution of a salt of Glycyna. In its solubility in potassa and soda, Glycyna resembles alumina; but Vauquelin showed that it would not form alum by adding potassa to its liquid sulphate: and further by the sweet taste of its Salts he considered it clearly distinguished from that earth. It differs also from Yttria in not forming crystallizable Salts, in not being soluble in the fixed alkalis, and in not being precipitated by oxalate of ammonia, nor by tartrate or citrate of potash.

References to § 3.

(a.) Vauquelin, *An. de Ch.* vol. xxvi. p. 155, and *An. d'Hist. Nat.* vol. xv. p. 358—395. (b.) Klaproth, *Beitrag*, vol. iii. p. 215. (c.) Ekeberg, *An. de Ch.* vol. xliii. p. 277, or *Jour. des Mines*, vol. xii. p. 25.

Sect. IV.—*Thorinum*.

(516.) At the time of forming the outline of this Treatise, it was believed, on the authority of Berzelius, that a peculiar earth existed, to which he gave the name of Thorina; and from analogy with other earths it was supposed to have a metallic base, which would of course be Thorium. Berzelius has, however, subsequently found that this supposed earth, of which he had only a very small quantity, was a phosphate of yttria. Still more recently he has obtained another earth, which he believes to be simple, and proposes that it should still continue the name of Thorina among the earths. At present, however, very little is generally known of this substance.

Sect. V.—*Aluminium*.

(517.) The experiments of Sir H. Davy on the earth alumina gave sufficient evidence of the existence of this Metal, though they were not so successful as those made on some of the other earths. He submitted alumina itself to the action of Voltaic Electricity, and obtained metallic globules, consisting chiefly of potassium, but which, when carefully separated and again oxidized, afforded both potash and alumina. Results of the same nature were obtained from potassium and from mercury, when acted upon in a state of mixture with alumina. By exposing the earth at a white heat to the vapour of potassium, potash was formed, and among the alumina there appeared small particles of a grey colour and metallic lustre, which again became white on exposure to the air, or if placed in water decomposed, it producing a slight effervescence. Alumina, a well-known earth, the oxide of this Metal, will be described in the following subsection.

(518.) A. "Alum is a salt which was known many centuries ago, and employed in dyeing, though its component parts were unknown. The alchemists discovered that it is composed of sulphuric Acid with an earth; but the nature of this earth was long unknown. Stahl and Neuman supposed it to be lime; but in 1728, Geoffroy, jun. proved this to be a mistake, and demonstrated that the earth of alum constitutes a part of clay. (a.) In 1754, Margraaf showed that the basis of alum is an earth of a peculiar nature, different from every other; an earth which is an essential ingredient in clays, and gives to them their peculiar properties. (b.) Hence this earth was called *Argil*; but Morveau afterwards gave it the name of *Alumina*, because it is obtained in the state of greatest purity from alum. The properties of Alumina were still further examined by Macquer in 1758 and 1762, (c.) by Bergman in 1767 and 1771, (d.) and by Scheele in 1776; (e.) not to mention several other Chemists who have contributed to the complete investigation of this substance. A very ingenious Treatise on it was published by Saussure, jun. in 1801." (f.) Thomson, *Syst.* vol. i. p. 373.

Alumina forms a part of many minerals. It exists pure in the corundum genus, of which the sapphire and ruby are species; owing their colours only to very minute portions of metallic oxides. Alumina forms the characteristic ingredient in clays and marls, and it is to this earth that they are indebted for their plastic properties.

(519.) B. To obtain pure Alumina, let alum be dissolved in about twenty times its weight of water, then add a small quantity of carbonate of soda in solution to precipitate a little iron, with which almost all alum is contaminated. After this let the Liquid be filtered into a solution of pure ammonia, being careful to keep the latter alkali in excess. The ammonia unites with the sulphuric Acid, and the Alumina falls down in a white flocculent precipitate, which must be well washed and dried. According to Saussure there is a considerable difference in the appearance of precipitated Alumina, arising from the state of dilution in which it exists in its solution.

(520.) C. Pure Alumina is a white, bland powder, adhering to the tongue, but neither exciting smell nor taste. It forms a paste with water: is infusible, except by the flame of the Gas blow-pipe. There is a peculiar smell excited by breathing upon an argillaceous limestone, but this smell depends upon the simultaneous presence of oxide of iron. The Specific Gravity of Alumina is 2.0, according to Kirwan. When first precipitated Alumina is a hydrate, but by a red heat the water is driven off, and the chemical properties of the earth itself undergo some change. On this subject consult Saussure's Memoir, and some interesting recent experiments by Thomson. (g.)

(521.) D. E. F. G. H. I. With the substances in these classes Alumina does not combine.

(522.) K. In considering the action of Alumina with the bases, we may first notice its ready power of union with other earths by fusion. From this property arises much of its utility in the Arts. Thus it unites with lime, barytes, strontia, magnesia, and silica, and probably would do so with the other similar bodies. With those named it combines both in the humid and dry way. The affinity for barytes is very marked, for it

communicates to Alumina a degree of solubility beyond that which is natural to it, so that when equal parts of these earths are boiled in water, both are dissolved. Vauquelin states that if barytic water be added to a solution of muriate of Alumina a precipitate falls consisting partly of both earths. (h.) This, however, is denied by Chenevix and Durracq. The effect of strontia is analogous, for if five parts of this earth be boiled with one of Alumina, a portion of Alumina is rendered soluble, while another portion remains in the state of an insoluble compound of strontia and Alumina. Scheele observed, that when Alumina is added to lime-water, an insoluble compound of the two earths is precipitated. Chenevix found that if a solution of potash be boiled on a mixture of lime and Alumina, the latter is dissolved; together with a greater proportion of lime than is due to the solvent power of the water alone: while if the alkaline solution be boiled on lime alone, no more lime is dissolved than is due to the water of the solution; a proof that the solvent power of the water over the lime is promoted by the Alumina.

By the intense heat of the Gas blow-pipe, or of oxygen alone, Alumina and lime may be fused together when the Alumina is in excess: but Alumina and magnesia will not run together at any heat, according to Kirwan and Gnyton. There is, however, some affinity between Alumina and magnesia, for magnesia alone cannot be entirely precipitated from any of its solutions by ammonia, while if Alumina be present its precipitation is complete. Thus Chenevix found, that if an excess of Ammonia be added to a solution of muriate of magnesia, mixed with a large proportion of muriate of Alumina, nothing remained in solution but muriate of ammonia; the two earths being precipitated in combination, and their mutual affinity was even sufficient to resist the action which potash exerts on aluminous earth.

The mutual attraction between silica and Alumina is shown by an experiment of Morveau, in which, when a solution of silicate of potash and of Alumina and potash are mixed, the two earths are precipitated in combination, by which the properties of each are modified. So also at a very intense heat this affinity is developed by the earths entering into fusion and forming a milky glass or enamel.

Alumina unites also with some of the metallic oxides by fusion, forming enamel of different colours.

Acids dissolve Alumina with ease, especially when it has been recently precipitated. The Salts thus formed are, for the most part, soluble in water, and, generally speaking, their tendency to crystallization is small. The arseniate, seleniate, tungstate, mullate, urate, saccharate, are insoluble; but for the properties of these Salts we must refer to the more extended chemical systems.

There is, however, one salt of Alumina of too great commercial importance to be passed by without further notice. Alum is a triple compound of Alumina, sulphuric Acid, and any one of the three alkalis proper, with some water of crystallization. Of this salt there are four varieties. We could have wished here to describe more fully the natural and chemical history of a substance so extensively employed in numerous Arts, but our space not permitting, we refer the reader to an excellent synoptic view of the subject given in Professor Thomson's *System*, vol. ii. p. 537.

(523.) L. One of the marked properties of the aluminous Salts is that they have in general a sweet taste,

**Chemistry.** like those of glycyna. They are not precipitated from their solutions by oxalate of ammonia, nor by tartaric Acid, which distinguishes them from those of yttria. They are not precipitated by prussiate of potash, nor by tincture of galls, in which respect they differ from the salts of glycyna and yttria. If sulphuric Acid and then sulphate of potash be added to a salt of Alumina, and the mixture be left at rest, crystals of alum speedily form therein. Phosphate of ammonia produces a white precipitate; and hydriodate of potash a white flocculent precipitate, which speedily becomes of a permanent yellow colour.

(524.) M. The uses of Alumina and its compounds in the Arts and Manufactures are both numerous and important. Every variety of porcelain consists of some combination of argillaceous and silicious earths; though in the coarser kinds of pottery, sand and other impurities enter in considerable proportions. Silica, it is true, generally predominates even in the best porcelain clays, yet it is upon the Alumina that the essential properties of the compound depend. It is to this latter earth that the clay owes ductility in working, and tenacity in baking.

Generally speaking, the native porcelain clays increase in value in proportion to their purity. If more than five or six per cent. of lime be present, the clay becomes too fusible; if too great a proportion of oxide of iron be present, the porcelain acquires a red or brown tint when it is baked.

Of the porcelain clays the kaolin and petunze of the Chinese are the most celebrated. According to the analysis of Vauquelin, the former consists of silica 71, Alumina 11.5, lime 5.5. The purest clays that have been discovered in Europe result from the natural decomposition of rocks, containing a large proportion of feldspar. Such is the Cornish clay which is sent to Swansea, Worcester, and Coalbrook Dale. Magnesia seems also to be applicable to the same purpose, for Gohbert found that a clay which had long been used with success in the manufacture of porcelain, consisted almost entirely of silica and carbonate of magnesia.

The colours on porcelain result from the fusion of certain metallic oxides; thus the purple precipitate of cassius, a preparation of gold, produces the carmine colour; and with a larger proportion of lead in the flux, the same substance gives a purple. Peroxide of iron produces rose-red; white oxide of antimony mixed with oxide of lead and silica gives a yellow; oxide of cobalt, blue; oxide of copper, green; and various shades of brown arise from using different proportions of the oxides of manganese, copper, and iron. The gilding upon china is performed by laying on the gold ground down to an extremely minute state of division in a varnish of borax and gum-water, which is fixed in burning by the fluxing properties of the borax, and afterwards polished with the burnisher.

Crucibles and retorts are formed from a clay containing much oxide of iron; and the Hessian crucible clay consists, according to Vauquelin, of silica 69, Alumina 21.5, charcoal 1, oxide of iron 8.0. The singular properties of alum are taken advantage of for the following purposes. To render wood fire-proof, which it effects to a very considerable extent. It will aid the separation of the serous and watery parts of cream in churning butter. The chandlers add it to tallow, for the purpose of giving hardness. It is used in silvering

and lackering on copper and brass. It possesses a singular property in clearing turbid water, by producing a precipitate which settles to the bottom. It is used in tanning and dyeing the finer kinds of morocco leather. In dyeing cotton goods also it is of essential importance as it both prepares the vegetable fibre for receiving the colours, and aids the formation of an actual chemical combination between its own base, the colouring matter, and the cotton that is to be dyed. In Medicine it is applied both internally and externally as an astringent. It adds to the tenacity of bookbinders' paste, and helps to preserve it.

The last of the uses of alum to which we shall advert, is in the formation of that singular substance Homberg's Pyrophorus.

(525.) "Let three parts of alum and one of flour or sugar be melted together in an iron ladle, and the mixture be dried till it becomes blackish and ceases to swell; if it be then pounded small, put into a glass phial, and placed in a sand-bath, heated till a blue flame issues from the mouth of the phial, and, after burning for a minute or two, be allowed to cool, this substance is obtained. It has the property of catching fire whenever it is exposed to the open air, especially if the air be moist." Such is Dr. Thomson's recipe, and we have frequently followed it, generally with success. Instead of a glass phial we place the mixture in a half-pint cucurbit, with a bit of glass tube luted into the mouth after the cucurbit is filled. The whole is submitted to a low red heat in a crucible of sand, placed within a small portable furnace. A blue flame issues from the orifice of the glass tube which may be suffered to burn for a quarter of an hour. The whole should then be withdrawn from the fire, and the tube closed with a piece of lute. When the whole is cool, the pyrophorus, a black pulverulent substance with some lumps, should be rapidly transferred to a dry stoppered bottle, and most carefully preserved from the air. In this manner we have kept it good for years, opening it only occasionally. If the pyrophorus does not ignite speedily when taken from the phial, the mere process of breathing on it will frequently cause a vivid ignition.

Homberg discovered this substance accidentally about the commencement of the XVIIIth century. Its singular properties have excited the attention of many Chemists; and Davy has made it appear that the igniferous property, for inflammable we ought not to say, depends upon a small quantity of potassium which is produced from the decomposition of the potash in making the pyrophorus.

#### References to § 5.

(a.) *Mém. Acad. Par.* 1728, p. 303. (b.) *Mém. Acad. Berlin*, 1754 and 1759. (c.) *Mém. Acad. Par.* 1728. (d.) Bergman, *Opusc.* vol. i. p. 287, and vol. v. p. 71. (e.) Scheele, *Essays*, vol. i. p. 191. (f.) *Jour. de Phys.* vol. lii p. 289. (g.) *First Principles*, vol. i. p. 315. (h.) Vauquelin, *An. d'Hist. Nat.* vol. xv. p. 13. (i.) Chenevix, *Phil. Trans.* 1802, p. 346.

#### Sect. VI.—Magnesium.

(526.) For the discovery of this base we are indebted to that elaborate series of researches made by Sir H. Davy on the earths and alkalis in general.

When Magnesia, the oxide of this Metal, was submitted to galvanic action in its pure state, less effect was



**Chemistry.** produced than upon the other alkaline earths. This was attributed to its very imperfect conducting power, arising out of its insolubility. To avoid this difficulty, solutions of the sulphate, or nitrate of Magnesia, were galvanized in contact with mercury. Decomposition then took place; an amalgam of mercury and Magnesium was formed. Sir H. Davy experienced, however, some difficulty in attempting to separate the Magnesium from the mercury, by distilling off the latter in a tube filled with the vapour of naphtha. The glass of the tube was acted upon, so that he was obliged at a certain period of the experiment to desist. Davy, however, obtained a Solid, having the same general metallic appearance as the Metals from the other earths had. "It su k rapidly in water, though surrounded by globules of Gas, producing Magnesia, and quickly changed in air, becoming covered with a white crust, and falling into a fine powder, which proved to be Magnesia." (a.)

In a subsequent experiment, potassium was passed over Magnesia at a high temperature, and quicksilver introduced into the tube while hot. Thus an amalgam was obtained, from which the potassium was abstracted by the action of water. Thus a solid white metallic mass was obtained, which, by exposure to the air, became covered with a dry white powder; and by the action of hydrochloric acid, hydrogen was evolved in considerable quantity, and a solution of Magnesia obtained.

With Magnesium, oxygen combines to form the earth under examination, in the following subsection; and it is supposed to combine also with chlorine, as will there be noticed. It seems to be beyond a doubt, that if obtained in sufficient quantity, it would be found to possess all the ordinary characteristic properties of the metallic bodies.

#### Subsect. 1.—Magnesia.

(527.) A. About the beginning of the XVIIIth century, a Roman Canon exposed a white powder for sale at Rome, as a cure for all diseases. This powder he called *Magnesia Alba*. He kept the manner of preparing it a profound secret; but, in 1707, Valentine informed the public that it might be obtained by calcining the luvium which remains after the preparation of nitre: (b.) and, two years afterwards, Slevogt discovered that it might be precipitated by potash from the mother ley of nitre. This powder was very generally supposed to be lime, till F. Hoffman observed that it formed very different combinations with other bodies. (c.) But little was known concerning its nature, and it was even confounded with lime by most Chemists, till Dr. Black made his celebrated experiments upon it in 1755. Margraaf published a dissertation upon it in 1759: (d.) and Bergman another in 1775, in which he collected the observations of these two Philosophers; and enriched them by adding many observations of his own. (e.) Butine of Geneva likewise published a valuable dissertation on it in 1779. (Thomson.)

Magnesia exists naturally as a constituent part of several minerals and rocks. It seems to communicate to all the steatite family their peculiar soapy feel. It forms a part of the saline ingredients of sea-water, and its sulphate forms the chief active principle of many of the natural saline springs, so much the resort of invalids.

(528.) B. Pure Magnesia may be obtained by dis-

solving sulphate of Magnesia in hot water, and then adding to the filtered solution, while yet hot, a solution of carbonate of potash or soda, as long as any precipitate appears. The process is aided by gently boiling the Liquid. Thus we obtain a pure carbonate of Magnesia, which may be decomposed by a red heat, leaving pure Magnesia: hence sometimes called *Calcined Magnesia*.

(529.) C. Magnesia is a white, light powder, soft to the touch, without smell, and possessing only a rather bitter taste. It slightly changes the vegetable blues to green. It is, perhaps, the most infusible of the earths. Dr. Clarke succeeded in melting it by the flame of the Gas blowpipe, though with difficulty. Pure Magnesia is only soluble in 1660 times its weight of water, according to Dalton. When precipitated it retains some portion of water by a feeble affinity, thus constituting a hydrate. There is also a native hydrate containing thirty per cent. of water.

(530.) D. None.

(531.) E. If Magnesia be heated in chlorine Gas, a decomposition takes place, oxygen is evolved, and chloride of Magnesium is formed. The chlorine absorbed is double the volume of the oxygen Gas evolved. When water is added to this compound, we have a well-known salt, which forms a part of the sea and many mineral waters. This salt, long called muriate of Magnesia, is, in fact, a hydrate of the chloride of Magnesium. It is a very deliquescent salt, soluble in twice its weight of alcohol, (0.817,) and in half its weight of water. When strongly heated, the water is dissipated, and in part decomposed. The hydrogen and chlorine escape, while the oxygen remains with the Metal to form Magnesia.

(532.) F. Unknown

(533.) G. M. Gay Lussac formed the iodide of Magnesium, but its properties are little known.

(534.) H. With the exception of sulphur, it does not appear that any action takes place between the non-metallic electro-positive elements and Magnesia. Sulphur combines, but not very intimately, with Magnesia, when the former is fused in contact with it; or when the two are boiled together in water. Hydrosulphuric Acid Gas when passed through which has Magnesia suspended in it, dissolves a small portion of the earth; but the properties of this compound are little understood.

(535.) I. With this class of bodies Magnesia has no action, save that which has been already mentioned under Magnesium. (526.)

(536.) K. With those metallic oxides that perform the part of bases, Magnesia has no action. With the Acids Magnesia readily combines as a base. Its Salts are in general of high solubility in water, and have for the most part a disagreeable, saline-bitter taste. They are crystallizable, but our space will not permit a detailed description of them. The carbonate and sulphate are, however, too important to be altogether passed over in silence.

(537.) The Carbonate of Magnesia, for medical use, is prepared as directed in Art. (528.) In this state it is a white powder, but having excess of base, so that it is not neutral. If, however, this powder be diffused through water, and a current of carbonic Acid Gas be passed through the Liquid, saturation is effected, and the powder is dissolved. The neutral salt thus formed, may be obtained by evaporation in the form of transparent hexagonal prisms with plane summits. The carbonate of Magnesia of commerce, consists of the first variety,

Chemistry. and is according to Thomson generally contaminated with some sulphate of lime.

(538.) Sulphate of Magnesia was originally procured by evaporating the mineral spring which rises at Epsom in Surrey; hence it acquired the name of *Epsom Salt*. "Some account of it was published by Grew, in 1675; and, in 1723, Mr. Brown published a description of the process employed in extracting it from the mineral water, and in purifying it. (f.) In Italy it is manufactured from schistose minerals, containing sulphur and Magnesia." (g.) It exists in considerable quantity in sea-water; and the uncrystallized residuum in the salt-pans after all the common salt is crystallized, consists partly of this salt dissolved in water. This residuum is usually called *Buttern*; and sometimes, in Scotland, *Spirit of Salt*. (h.) In England that term is applied to hydrochloric Acid.

Sulphate of Magnesia is soluble in its own weight of water at 60° Fahrenheit; and a much less quantity if the water boils. When exposed to the air it is efflorescent; and by heat it is fusible; the water of crystallization is then gradually driven off, but the actual decomposition of the salt cannot be effected by any elevation of temperature. Thomson supposes the crystallized salt to contain seven atoms of water.

(539.) L. The most characteristic property by which the salts of Magnesia are recognised, is that by adding a solution of phosphate of soda; no precipitate is produced; but then if ammonia also be added, a white precipitate falls down, which is a double phosphate of ammonia and Magnesia. The delicacy of this test, which was pointed out by Dr. Wollaston, is so great, that an extremely minute portion of Magnesia may be detected by it. If the experiment be made in a watch-glass, it is advisable to rub the point of a glass rod against the surface of the glass within the solution. This aids the deposition, and the precipitate appears in white lines wheresoever the rod has passed.

Sulphate of soda occasions no precipitate in a magnesian salt, but the alkalis, or their carbonates, produce a white flocculent precipitate.

Prussiate of potash throws down no precipitate from a solution of any salt of Magnesia: those excepted which are formed by the metallic Acids.

(540.) M. Magnesia is largely employed in Medicine. The sulphate is a cooling purgative; and the carbonate, or the pure earth, is used as a purgative and antacid.

#### References to § 6.

(a.) Davy, *Phil. Trans.* 1808; (b.) *Thesis de Magnesia Alba*; (c.) *Obs. Phys. Chem.* 1722, p. 105 and p. 177; (d.) *Opusc.* vol. ii. p. 20; (e.) *Opusc.* vol. i. p. 365; (f.) Brown, *Phil. Trans.* vol. xxxii. p. 348; (g.) *An. de Ch.* vol. xlviii. p. 80; Gehler, *Jour.* vol. iii. p. 549; Holland, *Phil. Trans.* 1816, p. 291; (h.) Thoms. *Syst.* vol. ii. p. 521.

### § METALS. CLASS II.

#### Sect. II.—Calcium.

(541.) A. This metal was one of the discoveries of Davy, made by means of the Voltaic battery.

(542.) B. It may be obtained by forming a paste of lime, or of sulphate of lime mixed with water into a cup, which is then to be placed on a metallic dish. Mercury is poured into the cup, and connected with the negative extremity of the pile; while, at the same time, the

positive wire is made to touch the metallic dish. Thus in time an amalgam of mercury and Calcium is formed, and is to be put into a small retort, with a little naphtha to cover it. The retort is to be connected with a tubulated receiver loosely corked. By heat the naphtha rises in vapour so as to fill the vessels; the mercury next comes over; and the Calcium remains within an atmosphere of naphtha.

(543.) C. This Metal appears to have the colour and lustre of silver, but its other physical properties are unknown.

(544.) D. The instant that atmospheric air is admitted to Calcium, the Metal absorbs oxygen, and burns with an intense white light, again returning to the state of lime. Lime is the protoxide of Calcium. See subsect. 1.

(545.) A superior oxide of Calcium is formed by passing oxygen Gas over ignited lime; the Gas is absorbed, and this oxide results, but its exact atomic constitution is unknown.

(546.) E. If lime be heated in chlorine Gas, one volume of chlorine is absorbed, and half a volume of oxygen being evolved, the chloride of Calcium is formed. It is also produced by fusing hydrochlorate of lime at a red heat. By addition of water the hydrochlorate is again formed.

(547.) F. The substance to be hereafter mentioned as fluete of lime, is by some Chemists supposed to be a true fluoride of Calcium.

(548.) G. Iodide of Calcium is formed by evaporating hydriodate of Calcium to dryness, and fusing the residuum.

(549.) H. The existence of compounds of sulphur and phosphorus with Calcium seems to be sufficiently well established. The phosphuret is formed by taking a glass tube, fourteen inches in length, and one-third of an inch in diameter, closed at one end, and well coated with clay, excepting an inch at the closed end. Into this is put a drachm or two of phosphorus; the tube is then filled with fragments of fresh burnt lime as large as peas: the mouth of the tube may be loosely stopped with paper, and its body passed through a table furnace, and heated to redness. A spirit-lamp is then applied to the sealed end, so as to fuse and volatilize the phosphorus. The vapour passing over the heated lime decomposes it, and a phosphuret of Calcium results. This substance was long called phosphuret of lime: it forms an amusing experiment by dropping a small piece of it into a glass of water. In a short time, bubbles of phosphuretted hydrogen Gas rise through the water and explode on reaching the surface.

The sulphuret of Calcium was formed by Berzelius, who passed a current of sulphuretted hydrogen over red-hot lime. The hydrogen of the Gas united with the oxygen of the lime to form water, and the sulphur united with the Calcium.

(550.) I. Calcium would doubtless unite with other Metals; but this and many other of its properties have as yet been little studied.

#### Subsect. 1.—Lime.

(551.) A. The nature of this, the protoxide of Calcium, has been already explained in Art. (542.) It does not exist pure in Nature, from its great affinity for water and carbonic Acid. But, in the state of a carbonate, it forms one of the most abundant and important substances in Nature. Whole mountains and vast tracts

Chem.-Gy. of country consist of immense strata of this carbonate in various states of purity, and deposited at different epochs in the existence of our Earth. Hence it is that, as it is slightly soluble, there are few springs of water, however pure, that do not contain some Lime.

(552.) B. Lime is readily obtained by the calcination of common limestone, in which the water and carbonic Acid are driven off: but as this will contain an admixture of other earths and metallic oxides, it is necessary for chemical purposes to employ pure pellucid Iceland crystal, or the whitest Carrara marble. Oyster-shells also afford good Lime.

(553.) C. Lime is a white pulverulent earth, not fusible, save by the heat of the Voltaic pile, or of the Gas blow-pipe. Specific Gravity = 2.3. It is not volatile. With water it presents several singular phenomena. If this fluid be sprinkled on fresh caustic Lime, great heat is produced and the water entirely disappears, entering into combination to form a solid hydrate of Lime. Mr. Dalton estimates the heat produced on such an occasion at 400° Fahrenheit. Pelletier even states that light is evolved, so as to be seen in a dark place. Lime absorbs moisture from the atmosphere and falls to powder. This earth is slightly soluble in water, perhaps to about the extent of 1-700th part; 1-752d according to a careful experiment made by Mr. R. Phillips. Mr. Dalton has shown that in the case of Lime, cold water is capable of taking up more than hot water, as seen by the following Table:

	at 60°	at 130°	at 212°
Grains of water to dissolve one grain of Lime . . . . .	778	972	1270
Grains of water to dissolve one grain of hydrate of ditto . . . . .	584	720	952

Lime-water possesses alkaline properties. When exposed to the air, the Lime unites with carbonic Acid and is precipitated. Gay Lussac, however, procured crystals of pure Lime, by placing a vessel of Lime-water with sulphuric Acid under an exhausted receiver. The crystals contained one atom of Lime + one atom of water. (a.)

(554.) D. None.

(555.) E. The combination of chlorine with Lime is one of great importance from its extensive application in the process of bleaching. If slaked Lime (the protohydrate) be passed through a sieve in the state of fine powder, and then placed in contact with chlorine Gas, the Gas is absorbed with great avidity, much heat being evolved. When the Lime has taken up all the chlorine that it is capable of, it appears a dry white powder, known in commerce by the names of bleaching powder, or oxy muriate of Lime.

It consists, in fact, of Lime, chlorine, and water; and probably in the proportions of 1, 2, and 6 atoms of these elements. This powder is, in fact, a subchloride of hydrate of Lime. Dr. Thomson calls it dichloride of Lime, but no one name has met with universal adoption.

This substance is soluble in water to a considerable extent. By heat it is decomposed; the water first passing off; then decomposition of the Lime takes place, oxygen Gas is evolved, and chloride of calcium is formed. The purity of this substance being of great importance, has engaged the attention of our most eminent Chemists, as will be seen from the reference. (b.)

(556.) F. G. Unknown or not existent.

(557.) H. With some of these substances Lime may

be united, but the combinations are not of general importance. Part II.

It appears that by strongly heating Lime and sulphur some sulphuret of calcium is formed; but how far a true sulphuret of Lime exists is not quite certain, though long believed. If this sulphuret of calcium be dissolved in water, or if one part of sulphur, three parts of hydrate of Lime, and ten of water, be boiled together, a deep orange-coloured Liquid is formed, and has been much employed in eudiometry. By some it is termed hydroguretted sulphuret of Lime, but in our nomenclature it would be (408.) hydrosulphite of Lime. If a current of hydrosulphuric Acid Gas be transmitted through water, in which Lime is mechanically suspended, a *hydrosulphate* of Lime is formed, and may be separated as limpid crystals, soluble in water.

(558.) I. It is scarcely probable that any combination with these substances can be effected.

(559.) K. The Salts of Lime are numerous and important. Of these we can only name the sulphate, phosphate, and carbonate.

The sulphate is rapidly formed by art, and exists abundantly in Nature, known by the name of gypsum or plaster of Paris. By calcination it loses water, and the reabsorption, or addition of that Liquid, enables it to form an useful and cheap cement, or to take casts of gems and metals.

The phosphate forms to the amount of eighty-six per cent. a constituent of the bones of animals. The bi-phosphate, tri-phosphate, and quater-phosphate of Lime also exist, but Mr. Dalton considers the last an octo-phosphate.

The carbonate is the most abundant of the Salts of Lime. As chalk, limestone, and marble it must be familiar to every one. Although the affinity of carbonic Acid for Lime is very great, the substances do not readily combine, unless moisture be present. By a red heat the carbonic Acid is driven off from this salt in the Gaseous state; but if the escape of the Gas be prevented, Sir James Hall found that the limestone was fused by a heat of about 22° of Wedgewood's pyrometer (c.) This salt contains one atom of each of its proximate elements. A very elegant experiment by the late Professor Tenant of Cambridge, (d.) exhibits its ultimate decomposition. Carbonate of Lime is soluble in water, having an excess of carbonic Acid: hence arises the extensive calcareous deposit from the water of some springs. In these cases there exists in the water, carbonate of Lime dissolved in excess of carbonic Acid; by exposure to the atmosphere, the excess of carbonic Acid escapes, and the earthy salt is deposited.

(560.) L. Some of the Salts of Lime are soluble in water, others are not so. In such solutions no precipitate is produced by addition of pure ammonia; but potash and soda throw down caustic Lime. Upon solutions of Lime, the citrate or tartrate of ammonia produces no effect; but oxalate of ammonia exhibits a dense white precipitation. If an insoluble salt of Lime be boiled for some time in a solution of carbonate of potash, a white powder remains, consisting of carbonate of Lime, soluble with effervescence in nitric or muriatic Acid.

(561.) M. The uses of Lime are very various and important. The nitrate, when fused, forms Balduin's phosphorus. (d.) The chloride mentioned in Art. (555.) is now sold, when formed into an aqueous solution, under the name of Labaracq's Disinfecting Liquid; and

Chemistry. Is thus a convenient mode of applying the long known properties of chlorine for removing dangerous or disagreeable miasmata, in fever hospitals, or the chambers of the sick.

The use of gypsum in taking casts, and as a cement for marble or stone, has been already noticed. Caustic Lime is of great service in Agriculture when spread upon some kinds of land, as it ameliorates the stiff clays, and powerfully assists the solution of vegetable matters to form the food of growing plants. The formation of mortar from caustic, or quick Lime as it is called, for building, must be within the observation of every one. The mode of its operation is this. When fresh burned Lime is mixed with water, a paste is first formed, but, in a short time, the fluidity entirely disappears, by the passage of the water into the solid form to constitute dry hydrate of Lime. Some combination of carbonic Acid also takes place, but this is for the most part superficial. Lime made from the chalk or limestone of different strata, varies considerably in goodness. Such variations depend on the admixture of small proportions of certain other earths and oxides. The Roman cement, as it is called, contains a proportion of alumina and oxide of iron. On the subject of mortar there is a valuable Work by M. Vicat, in French.

#### References to § 1.

- (a.) Gay Lussac, *An. de Ch. et Ph.* vol. i. p. 334.  
(b.) Dalton, *An. Phil.* vol. i. p. 15. and vol. ii. p. 6; Thomson, *An. Phil.* vol. xv. p. 401; Welter, *An. de Ch. et Ph.* vol. vii. p. 383; Ure, *Jour. Roy. Inst.* vol. xiii. p. 21; Gay Lussac, *An. Phil.* vol. viii. p. 218.  
(c.) Nich. *Jour.* vol. xiii. and xiv.; also Bucholz, vol. xvii. p. 229. (d.) *Phil. Trans.* vol. xi. p. 788. Consult also Davy, *Phil. Trans.* 1808, p. 333; and *An. Phil.* vol. iii. p. 360. Berzelius, *An. de Ch.* vol. lxxxi. p. 13.

#### Sect. II.—Strontium.

(562.) Strontium was first obtained by Sir H. Davy. Native carbonate of strontia was formed into a paste with water, and placed on a small platinum tray. A globule of mercury was then placed within a cavity made in the surface of the paste. The platinum was connected with the positive pole, and the mercury with the negative pole of a pile of about 100 double plates. Thus an amalgam of mercury and Strontium was shortly produced. The amalgam was introduced into a tube of glass made without lead, which was then filled with the vapour of naphtha, bent into the form of a retort, hermetically sealed. The mercury was then driven from the amalgam by heat, and the Strontium remained.

The lustre of Strontium is not considerable; it is difficult of fusion, and not volatile. It decomposes water with evolution of hydrogen Gas; and if exposed to atmospheric air, it again becomes strontia. This earth is then proved to be the oxide of Strontium; its properties will more fully be stated in the ensuing subsection.

#### Subsect. I.—Strontia.

(563.) A. "About the year 1787, a mineral was brought to Edinburgh by a dealer in fossils, from the lead mine of Strontian in Argyleshire, where it is found

imbedded in the ore, mixed with several other substances. It is sometimes transparent and colourless, but generally has a tinge of yellow or green. It is soft. Its Specific Gravity varies from 3.4 to 3.726. Its texture is generally fibrous; and sometimes it is found crystallized in slender prismatic columns of various lengths."

"This mineral was generally considered as a carbonate of barytes; but Dr. Crawford having observed some differences between its solution in muriatic Acid, and that of barytes, mentioned in his *Treatise on Muriate of Barytes*, published in 1790, that it probably contained a new earth, and sent a specimen to Mr. Kirwan that he might examine its properties. Dr. Hope made a set of experiments on it in 1791, which were read to the Royal Society of Edinburgh in 1793, and published in the *Transactions* about the beginning of 1794. These experiments demonstrate, that the mineral is a compound of carbonic Acid and a peculiar earth, whose properties are described. To this earth Dr. Hope gave the name of Strontites. (a.) Klaproth analyzed it also in 1793, and drew the same conclusions as Dr. Hope, though he was ignorant of the experiments of the latter, which remained still unpublished. Klaproth's experiments were published in *Crell's Annals* for 1793 (b.) and 1794. (c.) Kirwan also discovered the more interesting particulars of this new earth in 1793, as appears by his letter to Crell, though his dissertation on it, which was read to the Irish Academy in 1794, was not published till 1795. The experiments of these Philosophers were repeated and confirmed in 1797 by Pelletier, Fourcroy, and Vauquelin, (d.) and several of the properties of the earth still further investigated. To the earth thus detected, Klaproth gave the name of *Strontian* from the place where it was first found; and this name," with the omission of the final *n*, "is now generally adopted. Strontia is found abundantly in different parts of the World, and always combined with carbonic or sulphuric Acid." Thomson's *Syst.*

(564.) B. Pure Strontia is readily obtained by dissolving the native carbonate in nitric Acid, evaporating the solution till it crystallizes, selecting pure crystals, and driving off the nitric Acid by heat in a platinum crucible. Strontia contains strontium one atom + oxygen one atom.

(565.) C. Strontia thus obtained is a grey, pulverulent mass, having a violent affinity for water. By affusion of this Liquid, heat is evolved, and so much earth is dissolved that crystals separate on cooling. Dalton considers that these crystals contain twelve atoms of water + one Strontia. Strontia has alkaline properties, but, unlike barytes, it is not poisonous. (e.) The crystals of Strontia, when dissolved in alcohol, cause it to burn with a bright red flame.

(566.) D. By pouring an aqueous solution of Strontia into the deutoxide of hydrogen, a deutoxide of Strontia is formed.

(567.) E. If Strontia be heated in chlorine Gas, oxygen Gas is expelled, and a chloride of strontium is formed. The same takes place if hydrochlorate of Strontia be heated to redness.

(568.) F. G. Unknown, save that iodine decomposes Strontia, as chlorine does.

(569.) H. Action none very important, save that some of these bodies by aid of heat decompose the earth, and form sulphurets, phosphurets, &c. with its metallic base.

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(570.) I. Not considerable.

(571.) K. Strontia never performs the part of an Acid; but with Acids it universally acts as a base. Its Salts are more soluble than those of baryta, but less so than those of lime. The greater part are capable of crystallization.

(572.) L. A solution of these Salts affords precipitates with the sulphates, phosphates, and oxalates; but not with ferro-hydrocyanate of potassa. Succinate of ammonia gives a precipitate in solutions of barytic salts, but none in those of Strontia. The colour of its flame in alcohol forms also a good test.

(573.) M. None, save to give colour in pyrotechnics. Strontia is not poisonous.

## References to § 2.

(a.) *Edin. Trans.* vol. iv. p. 14. (b) vol. ii. p. 189. (c.) vol. i. p. 99. See also Klaproth's *Beitrag*, vol. i. p. 260; and *Jour. de Mines*, No. 5. p. 61. (d.) *An. de Ch.* vol. xxi. p. 113. 276. (e.) Pelletier, *An. de Ch.* vol. xxi. p. 120. (f.) Gay Lussac, *An. de Ch.* vol. xci. p. 60.

## Sect. III.—Baryum.

(574.) Such should be the spelling of this word, derived from *βαρὺς*, (heavy,) though we have at times inadvertently spelled it Barium, as is frequently done. This Metal was obtained by Davy in 1808, from the carbonate of baryta, by a process which we have already described in Art. (562.) with reference to strontium. The Metal has a dark grey colour, with a lustre inferior to that of cast iron. It is fused at a heat below redness; though solid at all ordinary temperatures. It did not rise in vapour till nearly a red heat, and then acted violently on the glass of the tube which contained it. By admission of atmospheric air or oxygen, it is converted into the earth baryta. (See subsect. 1.) It has been proved by Gay Lussac and Thenard to be capable also of uniting with an additional proportion of oxygen, so as to form a deutoxide, by passing oxygen Gas over pure baryta at a red heat. (g.) In the very curious experiments made with the Gas blow-pipe, by Professor Edward Daniel Clarke of Cambridge, he frequently reduced pure barytic earth to an appearance which himself and many Chemists regarded as the Metal Baryum. The quantities, however, so obtained were very small, and apparently superficial; insomuch that, beyond the appearance, no fully conclusive evidence of the reduction was afforded.

## Subsect. 1.—Baryta.

(575.) A. "Barytes was discovered by Scheele in 1774 and the first account of its properties published by him in his Dissertation on manganese. (a.) There is a very heavy mineral most frequently of a flesh colour, of a foliated texture and brittle, very common in Britain, and most other Countries, especially in copper-mines. It was known by the name of ponderous spar, and was supposed to be a compound of sulphuric Acid and lime. Gahn analyzed this mineral in 1775, and discovered that it is composed of sulphuric Acid and the new earth discovered by Scheele. (b.) Scheele published an account of the method of obtaining this earth from ponderous spar. (c.) The experiments of these

Chemists were confirmed by Bergman, (d.) who gave the earth the name of *terru ponderosa*. Morveau gave it the name of *Barote*, and Kirwan of Barytes; which last was approved of by Bergman, and is now" (with little change) "universally adopted. Different processes for obtaining Barytes were published by Scheele, Bergman, Weigleb, and Atzelius; but little addition was made to the properties ascertained by the original discoverer, till Dr. Hope published his experiments in 1793. (e.) In 1797, our knowledge of its nature was still further extended by the experiments of Pelletier, Fourcroy, and Vauquelin." (f.) Thomson's *System*.

(576.) B. Pure Baryta is best obtained by dissolving the native carbonate in diluted nitric Acid. This solution is to be evaporated so as to obtain crystals of the nitrate. These are decomposed by a red heat, leaving pure barytic earth. The atomic constitution of this oxide will be seen from the general Table in Part V.; and it may be well here to state, that from a wish to economize space, many statements of the same nature are not made under this reference, as they will all be found in the above-named Table.

(577.) C. Pure Baryta has a caustic taste, changes vegetable blues to green; and is capable of forming a soap with oils. As generally seen, it is fusible by a moderate heat, being a hydrate; but when obtained pure from the nitrate, it is so only under the most intense heat of furnaces or the Gas blow-pipe. Pure caustic Baryta is slaked by water, forming a hydrate with evolution of very great heat. If a solution of this earth be made in boiling water, and then allowed to cool slowly, regular crystals are produced. These contain Baryta one atom + water twenty atoms, according to Mr. Dalton.

(578.) D. When pure Baryta is heated to redness in oxygen Gas, a deutoxide of baryum is formed.

(579.) E. If pure Baryta be heated in chlorine Gas, a chloride of baryum is formed with evolution of half a volume of oxygen Gas for every volume of chlorine taken up. A similar substance is produced by heating hydrochlorate of Baryta to redness.

(580.) F. Unknown.

(581.) G. If the hydriodate of Baryta be heated to redness, an iodide of baryum is produced.

(582.) H. No combination is known, or very probable, between Baryta and these substances, but in some cases, Baryta, if heated with them, produces such union with its metallic base.

(583.) I. It is not probable that the Metals can combine with Baryta, neither has it been found that even those which have the most powerful affinity for oxygen decompose it.

(584.) K. With Acids, Baryta combines as a base, forming an extensive class of Salts. Its sulphate and carbonate exist naturally among mineral bodies. The Salts of Barytes have, generally speaking, less tendency to dissolve in water than the Salts of lime have. The affinity between sulphuric Acid and Baryta, is extremely powerful, but the sulphate is decomposed by boiling it with solutions of the alkaline carbonates, or by fusion with them; but the former process is attended with some singularities. This Salt is also decomposed by heating it strongly with one-sixth of its weight of powdered charcoal. With phosphoric Acid, Baryta forms a phosphate and a biphosphate. For a good detailed description of the Barytic Salts, we must refer our readers to Thomson's *System*, vol. ii. p. 497.

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(585.) L. The properties by which solutions of Baryta are recognised, are chiefly these. A solution of any sulphate produces a white precipitate insoluble in nitric Acid. Heat applied to one of its crystalline Salts, converts it into a carbonate, if the Acid be of a vegetable nature, but produces no change if the Acid be incombustible; or converts an hydrochlorate or iodate into a chloride or iodide of the metallic base. Prussiate of potash produces no precipitate in a Salt of Barytes, unless the Acid be one of the metallic class.

(586.) M. Baryta, or its Salts, may be considered at present useless, either in Medicine or in the Arts. Its action is, however, most powerful on the animal economy, as it is one of the most virulent poisons known.

## References to § 3.

(a.) Scheele, vol. i. p. 61 and 78, French Translation. (b.) Bergman's *Notes on Scheffer*, sec. 167. (c.) Crell's *Annals*, vol. iii. p. 3. English Translation. (d.) *Opusc.* vol. iii. p. 291. (e.) *Edin. Trans.* vol. iv. p. 36. (f.) *An. de Ch.* vol. xxi. p. 113 and 276. (g.) *Rech. Phys.* vol. i. p. 169.

## Sect. IV.—Lithium.

(587.) This Metal was obtained by Sir H. Davy, and subsequently by Gmelin, from the newly discovered alkali, Lithia. (See subsect. 1.) It has never yet been seen in any considerable mass, partly from its rarity, and partly from the very great rapidity with which it returns to an oxidated state as fast as it is formed by the action of the pile.

## Subsect. 1.—Lithia.

(588.) A. This alkali was discovered in 1818, by M. Arfwedson, a Swedish Chemist, engaged in the analysis of petalite, a mineral from the mine of Uto in Sweden. It has been subsequently discovered in spodumine, lepidolite, and in several sorts of mica. Its name, Lithia, is derived from *λίθος*, (stone,) marking its origin as distinguished from that of the other two fixed alkalis, potash and soda.

(589.) B. Berzelius has suggested the neatest process for the separation of Lithia from earthy minerals. One part of the mineral finely powdered is to be intimately mixed with powdered fluor spar, and this mixture heated with three or four times its weight of sulphuric Acid, as long as any acid vapours are disengaged. Thus the silica unites with fluoric Acid, and passes off in the state of silico-fluoric Acid Gas, whilst the alumina and Lithia unite with the sulphuric Acid. These Salts are to be dissolved in water, and then pure ammonia is to be added, and boiled in the solution to precipitate the alumina. The Liquid is to be filtered and evaporated to dryness, and then the sulphate of ammonia may be expelled by a red heat. Sulphate of Lithia remains. This alkali is supposed to contain one atom of oxygen + one atom of Lithium.

(590.) C. Lithia has a white colour; is fused by a red heat, and in that state is transparent; it changes vegetable blues to green. It is not deliquescent when exposed to the air; is not so soluble in water as potassa or soda; and scarcely at all soluble in alcohol.

(591.) D. Unexamined.

(592.) E. Chloride of Lithium is formed when hydro-

chlorate of Lithia is heated to redness, and is a very deliquescent substance, and readily soluble in alcohol. Part II.

(593.) F. G. Unascertained.

(594.) H. Sulphur may be combined with Lithia, as with potassa and soda.

(595.) I. It would seem that Lithia is not entirely without action on the Metals, seeing that it corrodes a platinum crucible in which it may be heated.

(596.) K. With Acids, Lithia forms Salts like the other alkalis: but these have as yet been little examined. Its saturating power is higher than that of either potassa or soda. The Salts of Lithia are soluble in water, but the carbonate much less so than the other alkaline carbonates.

(597.) L. Hydrochlorate of platinum, ferro-hydrocyanate of potassa, and infusion of galls, produce no precipitate in Salts of Lithia. But a solution of a carbonate of potash, added to a concentrated solution of a Salt of Lithia, produces a white precipitate. The phosphate of Lithia is also rather an insoluble Salt, in which respect it is distinguished from potassa and soda.

(598.) M. None at present known.

## References to § 4.

Consult Arfwedson, *An. de Ch. et de Ph.* vol. x. p. 84; Gmelin, *Gibb. An.* vol. lxii. p. 339; Clark, *An. Phil.* vol. xi.; Vauquelin, *An. de Ch. et Ph.* vol. vii. p. 284; Gmelin, *An. Phil.* vol. xv. p. 341.

## Sect. V.—Sodium.

(589.) This Metal was discovered by Sir H. Davy in 1807; and his experiments were detailed in the *Philosophical Transactions* of 1808. He found that if pure caustic soda, a substance to be described in the following subsection, were just moistened by merely breathing on it, and placed on a disc of platinum; the disc being connected with the negative pole of a powerful Voltaic battery, and a wire from the positive pole being brought in contact with the upper surface of the soda; decomposition gradually took place. Oxygen Gas was evolved at the positive wire, and globules of metallic Sodium appeared at the parts in contact with the platinum. (a.)

MM. Gay Lussac and Thenard subsequently discovered a process more purely Chemical, by which this alkali might be obtained (b.) in greater quantity. This is performed by heating soda and iron turnings to whiteness in a coated gun-barrel. The process has been slightly modified and improved by others, and full instructions may be obtained by consulting the Memoirs quoted in reference (c.)

(600.) Sodium at our ordinary temperatures is an opaque, metallic-looking Solid, having the lustre and nearly the whiteness of silver; but it is necessary to examine it when covered with a film of naphtha for the exclusion of atmospheric air. It is extremely malleable and ductile. It is lighter than water, having a Specific Gravity about .97. It is less fusible than potassium, but begins to lose its solid form at 120° Fahrenheit, and becomes fully fluid at 180° or 190°. It is not volatile even at the fusing heat of plate-glass. On being exposed to atmospheric air it soon unites with oxygen, and its surface becomes a stratum of soda; but in perfectly dry air it remains unchanged. It combines with oxygen Gas at ordinary temperatures slowly, and without ignition; at its fusing point the action is more energetic,

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but light is not evolved, unless the Metal itself be about red-hot. It decomposes water with effervescence and a hissing noise. In hot water this action is still more violent, but no flame is produced except from small particles, which may be driven off and ignited in their passage through the air.

Two or more oxides of this Metal are at present admitted by some. The first formed by fusing soda and Sodium together; in which case the oxygen seems to be shared between all the atoms of Sodium, and from this very circumstance it seems doubtful whether the grey substance so produced be a true definite compound or not. The next oxide, *soda*, is formed when Sodium is burned, a volume of air affording just oxygen enough to convert the Metal into an alkali. This seems to contain one atom of each of its elements; and in the state we usually possess it, there is also an atom of water which it retains with great obstinacy. But if the Metal be burned in excess of oxygen, another oxide is formed which appears to contain Sodium two atoms + oxygen three atoms. This substance is very fusible, and of a deep orange colour. When placed in water the excess of oxygen separates, and a solution of soda remains.

(601.) The chloride of Sodium is formed by burning the Metal in chlorine Gas; or by heating it in hydrochloric Acid Gas, in which case the hydrogen is set at liberty;—or by evaporating a solution of common salt, which in its crystalline form is a pure chloride of Sodium, having only a little water mechanically existent among its molecules. But when this substance (which is sometimes called a Salt inadvertently) exists dissolved in water, it is generally believed to be as a hydrochlorate of soda; and then is truly a Salt.

The chloride of Sodium, a most important and abundant substance, crystallizes in regular cubes: its varieties have been ably described by Dr. Henry. (d.) By heat it decrepitates, and then fuses into a solid mass. It dissolves in two and a half times its weight of water at 60° Fahrenheit, and hot water takes up very little more. Hence, as Dr. Henry well remarks, its solution crystallizes, not like that of nitre by cooling, but by evaporation. (e.)

(602.) Iodide of Sodium may probably be formed by a direct process, but it is certainly obtained by applying heat to the hydriodate of soda.

(603.) By heating Sodium in ammoniacal Gas, the hydrogen is disengaged, and an Iodide of nitrogen is formed. It unites also with sulphur, selenium, and phosphorus; but not with hydrogen.

(604.) Sodium may form alloys with all the Metals.

Its reagent action and useful applications, can only be sought for among the description of its oxides and Salts; save that the chloride (common salt) is a wholesome condiment to food, and a powerful antiseptic.

#### Subsect. 1.—Soda.

(605.) A: "Soda, called also *Fossil* or *Mineral Alkali*, because it was thought peculiar to the mineral kingdom, was known to the Ancients (though not in a state of purity) under the names of *νίτρον*, and *nitrum*. It is found in large quantities combined with carbonic Acid, in different parts of the Earth, especially in Egypt. But the Soda of Commerce is obtained from the ashes of different species of the *Salsola*, a genus of plants growing on the sea-shore; especially from the *Sal-*

*sola Soda*, from which the alkali has obtained its name. The Soda of Commerce is also called *barilla*, because the plant from which it is obtained bears that name in Spain. Almost all the *Algæ* also, especially the *Fuci*, contain a considerable quantity of Soda. The ashes of these plants are known in this Country by the name of *Kelp*, in France by that of *Varee*.

"Soda and potash resemble each other so nearly, that they were confounded together, till Du Hamel published his dissertation on common salt, in the *Memoirs of the French Academy* for 1736. He first proved that the base of common salt is Soda, and that Soda is different from potash. His conclusions were objected to by Pott, but finally confirmed by Margraaf in 1758." Thomson's *System*.

(606.) B. It would occupy more space than we can here afford, to describe fully the processes for obtaining pure Soda from barilla; but an excellent abstract is given in Thomson's *System*, vol. i. p. 326. The general features of it, however, may be collected from the process for potassa. (Art. 626.)

(607.) C. Soda when pure is a greyish white mass; highly attractive of moisture, and sufficiently caustic to corrode and dissolve the skin, or other animal matters. By exposure to air, however, it does not deliquesce like potassa, but absorbing water and carbonic Acid, it crumbles into a white powder.

(608.) D. None. E. See Art. (601.) F. Unknown. G. Unknown.

(609.) H. More remains to be discovered respecting the combinations of Soda with some of these bodies; that with sulphur has been examined, but its real nature is not very manifest. (e.)

(610.) I. Unimportant, though not absolutely non-existent.

(611.) K. The Salts containing Soda as a base are numerous and important. The carbonate, bicarbonate, borate, (borax,) phosphate, and sulphate, are employed in Medicine and the useful Arts.

(612.) L. The solutions of Salts of Soda may be recognised by the following properties; they are all soluble in water, and in a higher degree than those of potassa. Their base is not precipitated by any reagent whatever. The form of the crystals will serve to distinguish them from those of a Salt of potassa. This is especially remarkable in the sulphate. By fusion in platinum-wire with the blow-pipe, a rich yellow colour is communicated to the flame.

(613.) M. Soda is largely employed in the very important arts of soap-boiling and glass-making.

#### References to § 5.

"(a.) *Ph. Trans.* 1808. (b.) *Recherches*, vol. i. p. 74. (c.) Tennant, *Ph. Trans.* 1814; Mandel, *Camb. Phil. Trans.* vol. ii.; Thenard, *Traité de Chimie*; *An. Phil. N. S.* vol. vi. p. 233; Brunner, *Jour. Roy. Inst.* vol. xv. p. 279. (d.) *Phil. Trans.* 1810. For analyses consult Thomson's *Syst.* vol. i. p. 341. (e.) Figuier, *An. de Ch.* lxiv. p. 59.

#### Sect. VI.—Potassium.

(614.) A. This Metal was discovered by Sir H. Davy in 1807, and from its nature can only exist under peculiar artificial circumstances, or in combination with other elements.

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(615.) B. To the process by which Potassium was obtained we have already adverted in the mention made of Sodium; (599.) for the same measures must be taken in procuring both Metals. As before, we must on this point refer our readers to the more ample details of original Memoirs. (a.)

(616.) C. At about 32° Fahrenheit it is hard and brittle, exhibiting a crystalline structure. At about 50° Fahrenheit it is a soft malleable solid, having the lustre of polished silver. At 70° Fahrenheit it is a semi-fluid substance, having in small globules a resemblance to mercury; but at 150° Fahrenheit it becomes quite fluid. At a heat about redness it may be volatilized unchanged. It is a conductor of heat and electricity. Its Specific Gravity has been variously stated from .8 to .9 referred to water as unity.

(617.) D. Potassium unites with oxygen, even though the Gas be dry, at ordinary temperatures; but by the aid of heat it burns therein with brilliancy. When the Metal is brought in contact with water, a violent action ensues; the water is decomposed with evolution of flame, and the protoxide of Potassium remains in solution. This protoxide is potassa. (See subject 1.) But when Potassium is burned in the open air, or in oxygen Gas, it is converted into an orange-coloured substance, which is a superior oxide of the Metal. This is by some called the peroxide; we venture, in adherence to our system, to call it the tritoxide, to mark that it contains oxygen three atoms + Potassium one atom. The same substance is formed by passing oxygen Gas over potassa at a red heat. Potassa has a very strong affinity for water, so that even fused caustic potassa is a hydrate, containing potassa one atom + water one atom. But anhydrous potassa may be obtained by fusing nitrate of potassa in a crucible of gold. Mr. Dalton has given a Table showing the proportion of real alkali in solutions of potassa of different Specific Gravities. (b.)

(618.) E. If Potassium be heated in chlorine Gas, its combustion is more vivid than in oxygen; and a chloride of the Metal is formed. The same substance results from heating to redness hydrochlorate of potassa formed by dissolving carbonate of potassa in hydrochloric Acid; the hydrogen of the Acid uniting with the oxygen of the potassa to form water, which is dissipated by the heat.

(619.) F. Unascertained.

(620.) G. Iodide of Potassium may be formed by heating Potassium with iodine in a green glass tube. Light is evolved during the combination. This iodide is volatilized by heat; and by solution in water its elements take to themselves hydrogen and oxygen respectively from the water, and a solution of hydriodate of potash results.

(621.) H. With hydrogen, Potassium forms two compounds, the one gaseous, the other solid. The former is produced simply by heating Potassium in hydrogen Gas. The latter by a similar process, but at a very moderate heat. Potassium unites also with sulphur, selenium, and phosphorus.

(622.) I. Potassium has a great tendency to unite with many of the other Metals, especially with mercury; and the amalgam so formed is capable of dissolving all other metallic bodies.

(623.) K. In consequence of the strong affinity which this Metal bears for oxygen, it reduces the oxides of all other Metals when heated with them. When added to the mineral acids, Potassium decomposes water, becomes

oxidized, and a salt of potassa remains in the solution.

(624.) L. M. All action to which this head refers, will more properly appear in the corresponding part of the subsection on potassa.

Part II.

Subject. 1.—Potassa.

(625.) A. If a sufficient quantity of wood be burned to ashes, and these ashes be afterwards washed repeatedly with water till it come off free from any taste, and if this Liquid be filtered and evaporated to dryness, the substance which remains behind is Potash: not, however, in a state of purity, for it is contaminated with several other substances, but sufficiently pure to exhibit many of its properties. In this state it occurs in Commerce under the name of Potash. When heated to redness many of its impurities are burned off; it becomes much whiter than before; and is then known in Commerce by the name of Pearlash. Still, however, it is contaminated with many foreign bodies, and is itself combined with carbonic Acid Gas, which greatly modifies its properties.

“That Potash was known to the ancient Gauls and Germans cannot be doubted, as they were the inventors of soap, which Pliny informs us they composed of ashes and tallow. These ashes (for he mentions the ashes of the beech-tree particularly) were nothing else but Potash: not, however, in a state of purity. (c.) The *scoria*, too, mentioned by Aristophanes and Plato, appears to have been a lie made of the same kind of ashes. The Alchymists were well acquainted with it; and it has been in every period very much employed in Chemical researches. It may be said, however, with justice, that till Berthollet published his process in the year 1786, Chemists had never examined Potash in a state of complete purity.” Thomson’s *System*, vol. i. p. 328.

Besides forming a part of many vegetable substances, Potassa is found in several animal fluids. Also in some minerals, as the leucite, lava, pumice, and in feldspar and zeolites, sometimes to the amount of eighteen per cent.

(626.) B. To obtain pure Potassa, take pearlash and dissolve it in twice its weight of hot water. To the solution add an equal weight of fresh-burned quicklime, slaked, and then formed into a cream with water. Boil these together in an iron kettle, for half an hour, continually stirring. Then filter out, or pour off the clear alkaline solution, and evaporate it to dryness in a silver capsule. Put the dry mass into a bottle, and add pure alcohol so as to dissolve out as much alkali as possible. Then separate again the alcohol by distilling it over from off the Potassa in a silver alembic with a glass head. Pour the fused residuum upon a silver capsule, and as soon as it is cool enough, let the cake be broken up and kept in well-closed phials. Potassa thus prepared is still a hydrate containing alkali one atom + water one atom.

(627.) C. Pure Potassa is a white, solid substance, highly caustic, fusible by a heat rather above redness, but not volatile. The solid hydrate has its apparent properties greatly similar. When quite dry it is a non-conductor of electricity.

(628.) D. If oxygen Gas be passed over Potassa in a closed tube at a red heat, an additional proportion of that element enters into combination, and the tritoxide

**Chemistry.** of potassium is formed. We term it the tritoxide, as containing potassium one atom + oxygen three atoms, on the principles we have laid down for our guidance, (110.) &c.; but this substance has been hitherto called the deutoxide or peroxide, seeing that the combination of one atom of metal + two atoms of oxygen has not yet been recognised.

(629.) E. When chloride of potassium is dissolved in water, a solution of hydrochlorate of potassa results; and conversely when the latter salt is evaporated to dryness, the metallic chloride is the only remaining product.

(630.) F. Little examined.

(631.) G. If iodine be agitated in a solution of Potassa, both an iodate and an hydriodate are formed; the latter being much the more soluble salt of the two.

(632.) H. The action of some of these bodies with Potassa is rather complicated, in some cases a union with the Potassa seems to be formed, in others the alkali is decomposed, and its metallic base forms the basis of the resulting compound. The hydrosulphate of Potassa, a useful test, is formed by passing a current of hydrosulphuric Acid Gas through a solution of Potassa; and it is capable of crystallization.

(633.) I. Potassa exerts a solvent action on some of the Metals.

(634.) K. With Acids Potassa forms, as a base, a most numerous and important class of Salts. Nitre, the nitrate of Potassa, is an anhydrous salt, containing an atom of each of its proximate elements; when fused it is called *Sal prunella*. *Pearlash* and *Potash* of Commerce are carbonates of Potassa of variable degrees of purity. The proportionate composition of the carbonates of Potassa may be seen from the general Table in Part V. Sulphate of Potassa is employed in Medicine, and was formerly called *Sal Polychrest*. *Prussiate of Potash*, as it was long called, is the ferro-hydrocyanate, a delicate and useful test for distinguishing metallic solutions.

(635.) L. Potassa in solution is usually in the state of a salt, it may be known by the following properties. The forms of the crystals. That a granular crystalline precipitate is produced by addition of tartaric Acid: by this it is well distinguished from soda. By not being precipitated by any preparation of nut-galls, nor by ferro-hydrocyanate of Potassa. By giving an orange-coloured precipitate with a solution of platinum in nitromuriatic Acid: a property not possessed by soda or lithia.

(636.) M. Potassa in its various states performs several valuable services in Medicine and the Arts. Nitre is a powerful antiseptic, and an essential ingredient in common gunpowder. The alkali is used also in soap-boiling, glass-making, &c.

#### References to § 6.

(a.) Davy, *Phil. Trans.* 1808. Ritter, *An. de Ch.* vol. lxvi. p. 92; Gay Lussac and Thenard, *Mém. d'Arcueil*, vol. ii. p. 299; *Recherches*, vol. i. p. 74; *Phil. Mag.* vol. xxxv.; Tenant, *Phil. Trans.* 1814; Woodhouse, *Nich. Jour.* vol. xxi. p. 290; Curmdan, *Nich. Jour.* vol. xxiv.; Bucholz, *Nich. Jour.* vol. xxix. p. 186; Murray, *Nich. Jour.* vol. xxviii.; *An. Phil. N. S.* vol. vi. p. 233; Brunner, *R. I. Journ.* vol. xv. p. 279. (b.) Henry, *Chemistry*, vol. i. p. 528. Ed. 10. (c.) Plin. *Hist. Nat.* lib. xviii. c. 51.

## METALS. CLASS III.

### Sect. I.—Manganese.

(637.) A. The most abundant ore of Manganese, the black oxide, has long been known; and very soon after the study of minerals assumed a scientific form, it was seen that a heavy, black, earthy substance, which had formerly been classed with iron-ores, must be separated from that genus. After several dissertations on this mineral, Bergman suspected it to be the oxide of a peculiar Metal, and at his desire Scheele undertook the examination of the substance, and by his Essay, published in 1774, and Bergman's of the same period, the metallic nature of its basis was established. This oxide is abundantly found in Devonshire and other parts of England: its other ores are the sulphuret, and a phosphate, wherein it is combined with iron, but these are rare.

(638.) B. From the great tendency of this oxide to vitrification, fluxes must not be employed for its reduction, an operation of great difficulty in consequence of the strong affinity of Manganese for oxygen. The only process by which the Metal has been obtained, is to submit oxide of Manganese, mingled with charcoal-powder and a little oil, to a most intense heat in a wind furnace. The Metal is fused in small globules, or in an imperfect button at the bottom of the crucible.

(639.) C. Manganese is of a greyish colour, and finely granular texture; softer than cast iron; Specific Gravity 8.013. (John.) It is very brittle, and of different fusibility. According to Morveau it melts at 160° Wedgewood, or at a point somewhat above iron.

(640.) D. Pure Manganese, being exposed to the air, gradually oxidates and crumbles into powder. If heated in oxygen Gas it undergoes combustion, and decomposes the vapour of water at a red heat. Perhaps there are few subjects of greater difficulty than the determination of the number of oxides which this Metal produces. We have on this subject valuable observations by Sir H. Davy, *Chem. Phil.* p. 367; John, *An. Phil.* vol. iii.; Berzelius, *An. de Ch.* vol. lxxxiii. and lxxxvii.; Gay Lussac, *An. de Ch. et de Ph.* vol. i.; Arvedson, *An. de Ch. et de Ph.* vol. vi. Davy admits only two oxides, John three, Berzelius five, which number he has subsequently reduced to four; (*An. Phil.* vol. iii.) and according to Chevallot and Edwards, there is another degree of oxidation still higher than the peroxide of all former Chemists, and possessed of acid properties. (*An. de Ch. et de Ph.* vol. viii.) Thenard is inclined to admit four oxides including the one last mentioned, which exists in the chameleon mineral. In this state of uncertainty it is impossible in a sketch like the present to give even an outline of the processes or reasonings of these Chemists, we therefore must confine ourselves to the two oxides the existence of which is well established. The first is precipitated from the Salts of Manganese, in the state of a white hydrate, containing, according to Davy, about twenty-four per cent of water; when this water is driven off by a red heat the oxide assumes an olive-green colour.

The native black oxide, hitherto called the peroxide, which must be abandoned, should Chevallot and Edwards's experiments be verified, is familiar to every tyro in Chemistry, as the substance from which oxygen

**Chemistry.** is principally procured. It is formed gradually by exposure of the olive oxide to the action of the air.

(641.) E. If metallic Manganese be exposed to heat in chlorine Gas their union is immediately effected, and light and heat are evolved. This chloride is a light, pink-coloured, flaky substance, and is obtained also by submitting hydrochlorate of Manganese to heat.

(642.) F. G. Unexamined.

(643.) H. Boron and silicon have not been united to Manganese. The phosphuret is easily obtained; and the carburet was found by Dr. Wollaston to constitute a peculiar substance filling small cavities in cast iron, and known in the foundries by the name of *keesh*. Bergman was able only to form a sulphuretted oxide of Manganese, but Vauquelin (*An. de Mus.* vol. xvii) obtained the true sulphuret; and Proust has described a native compound of the same elements. With nitrogen and hydrogen no combination has been formed.

(644.) I. Many of the probable alloys of Manganese have not yet been examined. It has, however, been united with iron, copper, tin, zinc, gold, and arsenic. It refuses to combine with silver, mercury, or lead.

(645.) K. Until the number and composition of the oxides of Manganese shall be finally settled, our knowledge of the Salts of Manganese must remain in a state of great imperfection. It has been the opinion of Chemists that all the Salts which contain Manganese as a base, contain the green oxide: recent experiments, however, seem to prove that this is not the case; but it frequently happens that in processes wherein the solution of the black oxide is effected, certain phenomena occur which prove that the Metal, as it dissolves, is reduced to a lower degree of oxidation.

Nitric Acid dissolves Manganese with evolution of nitric oxide G. s. But on the black oxide, its action is extremely feeble. If, however, sugar, or any substance affording carbon, be added, solution takes place with evolution of carbonic Acid Gas, thus the excess of oxygen is disposed of, and a Salt containing the green oxide is formed. Nitrous Acid acts more readily, because the oxygen which the Metal loses, goes to form nitric Acid, and the same Salt is produced as in the former case.

Protosulphate. Sulphuric Acid has but little action on Manganese, but this Salt is readily formed by dissolving the carbonate in sulphuric Acid. It crystallizes in rhomboidal prisms which are soluble in alcohol.

Some other sulphates are mentioned by Arfvedson: one has been long known to be obtained by distilling sulphuric Acid off black oxide of Manganese, and lixiviating the residuum; the oxide contained in this reddish-coloured solution of the Salt is not well ascertained.

Scheele, by dissolving peroxide of Manganese in sulphurous Acid, found that some oxygen quitted the Metal and, uniting to the Acid, converted it into the sulphuric, and thus the protosulphate was formed. The true sulphite has not been obtained.

The hyposulphite remains in solution when hyposulphite of lime is precipitated by sulphate of Manganese.

The hyposulphate is an exceedingly soluble Salt, remaining in solution after the sulphate has been obtained by evaporation from the Liquid wherein sulphuric Acid has acted upon oxide of Manganese.

Hydrochloric Acid dissolves Manganese with evolution of hydrogen Gas; with the green oxide no Gas is evolved, but by its action upon the black oxide, chlorine

is evolved. A solution thus formed contains hydrochlorate of Manganese, and this, by a proper heat, may be brought to the state of a chloride of the Metal.

Carbonate. A white powder precipitated from solutions of Manganese, by the addition of carbonate of potash.

Phosphate. This Salt occurs native, and, being scarcely soluble in water, is readily obtained artificially, by adding any alkaline phosphate to a solution of Manganese.

Seleniate. A soft, white, insoluble powder, fusible, and having the power of corroding glass. The biseleniate is soluble in water and crystallizable.

Arseniate. Formed by dissolving protoxide of Manganese in arsenic Acid. The Salt separates in a crystalline form. The addition of an alkaline arseniate to a solution of the Metal, produces the same effect. A double Salt may be formed by dissolving these crystals in sulphuric Acid. (John, *Gehl. Jour.* vol. iv p. 443.)

Antimoniate. A white, insoluble powder, produced by adding an alkaline antimoniate to a neutral solution of Manganese. (Berzelius, *Nich. Jour.* vol. xxxv.)

Chromate. Chromic Acid acts slightly on Manganese, but this Salt is best obtained by dissolving the metallic carbonate in the Acid. A brown solution is formed which is not capable of crystallization. (John.)

Tungstate. This Salt is an insoluble, infusible, white powder, formed by adding tungstate of potash to a solution of Manganese. (John.)

Acetate. Acetic Acid acts feebly on Manganese and its carbonate. The acetate may be obtained by evaporation in pink crystals, soluble in water and alcohol. (John.)

Benzoate, or Benzoic Acid, has a similar action, and the Salt produced is in the form of slender, colourless, prismatic crystals, soluble in twenty times their weight of water, and also in alcohol. This Salt contains no water of crystallization.

Succinate. Manganese and its carbonate are readily soluble in succinic Acid. The crystals produced have different forms, and though singly they are transparent, yet a number of them together have a pink hue. They are insoluble in alcohol, but water dissolves eighteen per cent.

Oxalate. Oxalic Acid dissolves Manganese or its oxide with effervescence, and a white powder is precipitated. The same Salt is produced by adding oxalic Acid to a solution of the Metal in any Acid. (Bergman.)

Tartrate. An insoluble Salt, which is formed by adding a neutral tartrate to a solution of barytes. The Acid dissolves oxide of Manganese.

Citrate. The citric Acid dissolves Manganese, forming a Salt of moderate solubility.

Silicate. A beautiful rose-red ore of Manganese well-known to Mineralogists, is, according to Berzelius, a combination of silica and the metallic oxide, wherein the former earth performs the part of an Acid. (*Afhandlingar*, vol. i. p. 105.)

#### Double Salts.

Tartrate of potash and Manganese. By mixing tartrate of potash with a solution of Manganese; after some time has elapsed, small prismatic reddish brown crystals are deposited, consisting of this double Salt, which is sparingly soluble in water.

(646.) L. In neutral solutions of Manganese the

Chemistry. following effects are produced. Fixed alkalis produce a white precipitate, which gradually blackens by exposure to the air. Prussiate of potassa and hydrosulphate of potassa a white precipitate. Hydrosulphuric Acid Gas whitens the solution, but produces no precipitate. Gallic Acid, infusion of galls, succinate and benzoate of ammonia, produce no effect; no other Metal throws down Manganese in the metallic state.

(647.) M. The common black oxide of Manganese is of great service to the Chemist for procuring oxygen; and it materially assists the glass-manufacturer in depriving glass of the green colour, which the iron present in the sand, or the flux, is liable to give to it. Bergman thus explains the theory of its action. Manganese in the state of black oxide produces a purple colour, but as a protoxide it gives no colour at all; iron, on the contrary, in a low state of oxygenation, gives a green tinge; but at a higher degree of oxidation it either remains infusible, or does not communicate colour. Hence it is evident that by these two oxides being present in proper proportions, each Metal passes to that state which is requisite for the formation of colourless glass. If the Manganese be in excess, the glass assumes a violet hue of any requisite intensity. Possibly, also, the oxygen of the Manganese may tend to the combustion of any carbonaceous matter present in the fused glass.

The black oxide of Manganese is largely employed in the preparation of chloride of lime for the bleachers.

For more ample details consult the references. (a.)

#### References to § 1.

(a.) Glauber, *Prosperitas Germaniæ*; Kaïm, *de metallis dubiis*, 1770; Rinman, *Mem. Acad. Stockh.* 1765; Scheele, *Essays*; Bergman, *Opusc.* vol. ii.; John, Gehlen's *Jour.* vol. iii.; Berzelius, *An. de Ch.* vol. lxxxiii. and lxxxvii.; Arfvedson, *Jour. de Phys.* vol. lxxxvii. and *An. de Ch. et Ph.* vol. vi.; Chevreton and Edwards, *An. de Ch. et Ph.* vol. viii.; John, *An. Phil.* vol. ii.

#### Sect. II.—Iron.

(648.) A. This Metal, although the most abundant and useful of all with which we are acquainted, was probably not the earliest known to the inhabitants of the Earth. Gold, silver, and copper, frequently occurring native, would soon attract attention from their properties, and become valuable auxiliaries to the artificer; but with the exception of those rare masses which seem to be of meteoric production, Iron must have remained unknown until accident, or a suspicion of their nature, led to the reduction of its ores. This knowledge, however, the Israelites possessed in the time of Moses, but how or whence they obtained it we know not. History informs us that about 200 years afterward, its use was introduced into Greece; but two facts tend to prove that even after another period of two centuries, it was extremely rare in that Country. The first, that the weapons of war were formed of a hard alloy of copper and tin, or ancient bronze; and the second, that a ball of Iron formed a prize given by Achilles during the Trojan war. Throughout Europe, indeed, bronze probably preceded Iron in the fabrication of swords and the heads of spears. The Celtic inhabitants of Britain have left durable memorials of their workmanship in

this beautiful alloy, and similar specimens have at different times been found in many of the Northern parts of Europe.

Some of the Salts of Iron occur native, but it is from the oxides that the Iron of Commerce is principally obtained; the sulphurets are also frequent. As a genuine mineral production, native Iron is of great rarity.

(649.) B. The reduction of the ores of this Metal on the large scale will come under consideration elsewhere, and for Chemical purposes the best soft Iron is to be selected, which is nearly pure, but may contain a little carbon, from which indeed this Metal is seldom entirely free.

(650.) C. The bluish-white colour of Iron is familiar to every one. Its hardness when pure is not very great; but when converted into steel, it may be rendered superior in hardness to almost every other substance. It is malleable when cold, and more so when hot, but in this respect it is inferior to gold and silver, though much superior to either in ductility. Its tenacity is great, and its Specific Gravity is stated from 7.6 to 7.87. Its fusing point is about 158° of Wedgwood. (McKenzie.) It is capable of permanent magnetism; but when pure it does not long retain this property. When Iron is violently heated its surface softens, and if two pieces in this state be hammered together a perfect union is effected. This property is common only to this Metal and platinum: it is of great utility, and known to artificers by the term *welding*.

(651.) D. Iron has an exceedingly strong affinity for oxygen; it rusts, that is oxidates, by free exposure to the atmosphere, and this effect is greatly accelerated by moisture. It gradually decomposes water also at ordinary temperatures; but some recent experiments of Dr. Hall (Brande's *Journal*) render it probable that this effect will not take place in pure water when the access of air is prevented. At a red heat it decomposes water with great rapidity; at a very intense heat it decomposes the fixed alkalis; but it is a singular circumstance, that though in the first case it takes oxygen from hydrogen, and in the second from the metallic bases, yet hydrogen and these bases are also capable of decomposing the oxides of Iron. Thus a curious problem in affinity is presented.

Two distinct oxides of Iron are recognised by all Chemists, the black and the red. The first has long been known as the *Martial æthiops* of the *Materia Medica*. It is best formed by exposing a paste of iron filings and water to the action of the air, moistening it repeatedly till the whole is oxidated, and then drying the powder by a gentle heat in an iron vessel. (De Roever, *An. de Ch.* vol. xlv.) The same oxide is precipitated from recently prepared sulphate of iron, by the addition of pure potash; and also by the combustion of iron wire in oxygen Gas. The red (per) oxide is formed by exposing iron filings to a red heat in an open vessel; a deep-red powder is produced, formerly termed *Saffron of Mars*.

Thenard and Gay Lussac have described other oxides of Iron, but at present considerable uncertainty exists on this subject. The atomic constitution of the oxides of Iron presents difficulties which have not yet been satisfactorily removed.

(652.) E. The chloride of Iron was discovered by Dr. J. Davy; it is obtained by dissolving the Metal in hydrochloric Acid, evaporating and exposing the residuum to a red heat, carefully excluding atmospheric air.

**Chemistry.** Thus obtained, the protochloride is of a grey colour and metallic lustre, fusible, but not volatile, and imperfectly soluble in water. (*Phil. Trans.* 1812.)

The deutochloride is obtained by burning Iron wire in chlorine Gas, or by evaporating an hydrochloric solution of the red oxide of Iron to dryness, with exclusion of atmospheric air. The substance is fusible, volatile, and may be condensed in minute crystals. It is soluble in water. (Sir H. Davy, *Phil. Trans.* 1811, and Dr. J. Davy, *Phil. Trans.* 1812.)

No analysis of these two compounds has a very strict agreement with the theoretical composition, supposing the former to consist of an atom of each substance, and the latter of one atom of Iron and two atoms of chlorine.

(653.) F. Unknown.

(654.) G. The only iodide of this Metal at present known, is formed by heating Iron in the vapour of iodine. It is a brown, fusible substance, soluble in water, producing a light green solution.

(655.) H. Of the combinations of Iron with combustibles, the carburets are by far the most important. When the Metal is in excess, steel is formed of different kinds, in proportion to the quantity of carbon; and it is stated by Mr. Mushet that no good steel contains more than one-sixtieth of carbon. In cast Iron, however, a greater proportion is found, the maximum of which is stated at one-fifteenth. For further particulars on this branch of manufacture, see reference (b.) Carbon, combined with a very small proportion of about one-twentieth, is the native plumbago, formerly called black lead. With regard to all the combinations of carbon and Iron, no satisfactory attempt can be made to bring them under the laws of the atomic theory; true Chemical combinations they nevertheless appear to be; and if so, the atom of one element must be united to more atoms of the other than we are in the habit of considering probable from the known constitution of other bodies. The phosphuret of Iron may be formed artificially, and also enters into the composition of what is termed *cold short Iron*. According to Berzelius the silicuret and seleniurets exist, and the boruret has been described by Gmelin. Two definite sulphurets exist native, the one known as magnetic pyrites, the other having so much sulphur that the magnetic property is destroyed. According to Mr. Hatchett, whose experiments are highly interesting, the carburets, sulphurets, and phosphurets of Iron have each some particular properties of combination, at which magnetism is most powerfully and permanently developed. Pure Iron being capable of little permanency in its magnetism, and again, when combined with too great a proportion of the nonmetallic combustible, losing the property altogether.

(656.) I. Strictly speaking, Iron may be considered capable of uniting with all the other Metals, though some of these combinations are of difficult formation: thus the great infusibility of both the Metals renders it difficult to form an alloy of platinum and Iron; and the volatility of mercury at a comparatively low temperature presented an obstacle to its union with Iron. This difficulty, however, Mr. Aikin indirectly surmounted.

(657.) K. The black oxide is soluble in most Acids forming light green solutions. The red oxide gives also, with most Acids, solutions of a reddish-brown colour, but is not so readily soluble as the black oxide. There exist then two distinct series of the Salts of Iron with the same series of Acids, viz. the protosalts and

the persalts, as for the present we may continue to call them.

Nitric Acid (Specific Gravity 1.16) acts gently upon Iron with very slight evolution of Gas, and a solution of protonitrate of Iron remains, darkly coloured by the nitrous Gas, which the Liquid at first retains, but which by combining with oxygen is gradually converted into nitric Acid, and becomes transparent.

If the above protonitrate be exposed to the air, or heated, it passes into the pernitrate, which is also the Salt obtained by the action of strong Acid upon the Metal; in this case a rapid decomposition takes place, and the protoxide and deutoxides of azote are abundantly evolved. This Salt is decomposed by a red heat, the red oxide remaining no longer soluble in nitric Acid. Hence, in analysis, if it be desirable to estimate the Iron in the state of protoxide, a few drops of nitric Acid are added previous to exposure to a red heat; but if the protoxide be required, the residuum is mixed with a little tallow or wax, and by exposure to a gentle red heat, a definite protoxide is obtained.

It is well to remember that the protoxide is soluble in nitric, but not in hydrochloric Acid. The peroxide is soluble in hydrochloric Acid, but not in nitric. No crystals of the pernitrate can be obtained by evaporation, but Vauquelin is said to have formed them indirectly.

Sulphuric Acid dissolves Iron and both its oxides. By the action of dilute Acid upon the Metal, hydrogen is evolved, and the protosulphate is produced. It is readily crystallized, but both in this state and in solution, if exposed to the air, the Metal proceeds to a higher degree of oxidation. This Salt is well known by the names of *green vitriol* or *copperas*; that which is met with in Commerce is chiefly produced by moistening native pyrites, with exposure to air and subsequent washing, evaporation, and crystallization. In the crystalline state, this Salt contains about forty-five per cent of water.

There are, according to Thomson, three subspecies of persulphate of Iron, but want of room will compel us here to refer to his system for a more particular account of them. The red persulphate of Iron being soluble in alcohol, which the green protosulphate is not, affords a ready mode of separating these Salts if mixed. The sulphite of the protoxide only is known, and may be formed by direct solution of the base in the Acid.

By the action of sulphurous Acid on Iron, the hyposulphite is produced, and its formation, as explained by Berthollet, is exceedingly instructive. The mutual action is violent, but no Gas is evolved. The Iron is oxidized at the expense of the Acid; half its oxygen combining with the Iron to form the black oxide, while the remaining sulphur and oxygen form hyposulphurous Acid, which unites with the base. (e.) Mr. Herschel obtained the same Salt by dissolving carbonate of Iron in sulphurous Acid, and boiling the solution upon sulphur. (f.) The protomuriate is formed by the action of muriatic Acid upon metallic Iron, but the *protoxide is insoluble in this Acid*, while by its action upon the *peroxide* the soluble permuriate is readily obtained.

A solution of fluoric Acid in water dissolves Iron; the solution does not crystallize by evaporation, but only becomes gelatinous.

A solution of carbonic Acid in water acts feebly upon Iron; with excess of Acid the Salt remains dissolved, but by boiling, or by long exposure to air, the Iron falls

**Chemistry.** down in the state of red oxide, still retaining some Acid; this process is daily seen in mineral waters. The carbonate has recently been found native, (c.) and may also be obtained by precipitating a solution of the sulphate by an alkaline carbonate. The rust which collects on exposed surfaces of Iron, especially if moist, is this carbonate more or less perfect.

The phosphate is produced by mixing solutions of phosphate of soda and sulphate of Iron, the perphosphate by mixing those of permuriate of Iron and phosphate of soda; it exists also native. (d.)

The borate precipitates, by the addition of solution of borate of soda to that of sulphate of Iron. Berzelius has described (*An. de Ch. et de Ph.* vol. ix.) the protoseleniate and biprotoseleniate, the perseleniate and biperseleniate. (g.)

The protarseniate and persarseniate of Iron exist native in Cornwall; the former may be produced by adding arseniate of ammonia to a solution of sulphate of Iron, and the latter by adding the same arsenical Salt to a solution of persulphate of Iron. Antimoniate of potash precipitates a white antimoniate of Iron from the sulphate. Chromate of potash produces from sulphate of Iron a tawny-coloured precipitate, consisting of oxide of chromium. Hence Vauquelin observes, that as the black oxide of Iron decomposes chromic Acid, protochromate of Iron does not exist. (Vauquelin, *An. de Ch.* vol. lxx.) He suggests that we might probably form a perchromate by employing some persalt of Iron instead of the protosulphate.

Alkaline molybdates, according to Scheele, produce a brown precipitate in the Salts of Iron. The tungstate exists native, (Wolfram,) and may be formed by adding an alkaline tungstate to a solution of sulphate of Iron. Acetic Acid readily dissolves Iron, and appears to form distinct Salts with the two oxides. The acetate is crystallizable, but the peracetate by evaporation is only gelatinized. The benzoate of Iron is a yellow, insoluble Salt, obtained by precipitation. The succinate is a crystallizable Salt, obtained by dissolving oxide of Iron in succinic Acid. But by adding succinate of ammonia to solutions of the persalts of Iron, a reddish, insoluble persuccinate is thrown down. On this property is founded one method of separating Iron from manganese. Thus by taking care to have the mixed solution of the Metals neutral, and the Iron in the state of a persalt, and then adding succinate of soda, the Iron may be entirely precipitated. By adding boletate of ammonia to a protosulphate of Iron no precipitate is produced; a solution of persulphate is entirely decomposed by these means, and the Iron thrown down in the form of a red powder. According to Braconnet, by this means Iron may be separated from manganese, lime, or alumina.

Sulphuric Acid gives a deep yellow colour to sulphate of Iron, but causes no precipitation. Oxalic Acid dissolves both Iron and its oxides; the protoxalate is soluble and crystallizes; the peroxalate has the contrary properties. The superoxalate of potash is, therefore, sold under the name of *Salt of lemons*, for the purpose of removing spots of ink from linen. From a persalt of Iron, mellitic Acid produces a yellow precipitate. Iron and its oxides are soluble in tartaric Acid; the prototartarate is soluble and crystallizable; the pertartarate has not these properties. Citric Acid dissolves Iron, and gradually deposits a white powder, which is stated to consist of a citrate and a bicitrate of Iron:

the former readily passing, if exposed, to the state of percitrate, which is a deliquescent and soluble Salt.

Part II.

According to Scheele, the saccharic Acid does not throw down Iron from its sulphate. Malic Acid gives, according to Scheele, a brown, uncrystallizable solution. Lactic Acid dissolves Iron, depositing delicate crystals, scarcely soluble in water. With protosalts of Iron, gallic Acid produces no precipitate, but with the persalts it forms the well-known black of our writing-ink; and this, though in reality a true precipitate of pergalate of Iron, is in so minute a state of division, as to remain suspended in the Liquid, especially if its consistency be increased by the presence of any mucilaginous substance.

Double sulphates of potash and Iron, and potash and ammonia exist. (Link, *An. de Ch.* vol. i.) The well-known tartarized tincture of Iron of the *Materia Medica*, is a double tartrate of potash and Iron. And the *Ferrum Ammoniatum* of the *Pharmacopœia*, is a double muriate of ammonia and Iron formed by sublimation. In this case the ammonia and the Acid are capable of carrying the oxide of Iron along with them in the volatile state, and the same property enables the muriatic Acid to carry over with it Iron in the process of distillation, which is the cause of the yellow colour in the common Acid of Commerce.

On a review of the above Salts of Iron it will appear, that for the most part the protosalts are crystallizable, and that the greater part of them are so soluble as not to be obtained by precipitation; that is supposing the formation of a protosalt to take place when a neutral solution of any Salt is added to a protosalt of Iron, the newly-formed Salt remains in solution; but whether this is the case, or whether no decomposition is effected, we have not at present any means of determining.

The persalts, on the contrary, rarely crystallize, and generally fall down in an insoluble state.

(658.) L. Much of the effects of reagents on the solutions of Iron, may be gathered from the preceding section. The most common tests of Iron are the infusion of galls, which gives no precipitate until the Iron is peroxidized by a few drops of nitric Acid, or by exposure to the air. The ferro-hydrocyanate of potassa giving a white precipitate with the protosalts, and a deep blue one with the persalts, is a most delicate test. Sulphuretted hydrogen produces no precipitate with the protosalts, but with the persalts gives a precipitate consisting of sulphur, because in this case the sulphuretted hydrogen is decomposed, and also the peroxide of Iron, which passes to the state of protoxide. "This Gas likewise precipitates Iron from its solution in some of the weaker vegetable Acids." Hydrosulphuret of potash gives a black precipitate with the persalts.

(659.) M. The countless uses of metallic Iron and steel need no enumeration; two of its Salts have been mentioned as employed in Medicine, and formerly it was given in several other states of combination. The peracetate is of great use to dyers, and considerable quantities of the sulphate are employed by hatters.

#### References to § 2.

(a.) Lavoisier, *An. de Ch.* vol. i.; Bergman, *Opusc.* vol. iii.; Vauquelin, *An. de Ch.* vol. xxii.; Morveau, *Ibid.* vol. xxxi.; Pronst, *An. de Ch.* vol. xxiii.; Thenard, *An. de Ch.* vol. vi.; Hassenfratz, *An. de Ch.* vol. lxix.; Bucholz, *Gehl. Jour.* vol. iii.; Berzelius, *An. Phil.*

Chemistry vol. iii. or *An. de Ch.* vol. lxxviii.; Gay Lussac, *An. de Ch.* vol. lxxx.; Meyer, *Crell's An.* 1784; Hatchett, *Phil. Trans.* 1804; Proust, *Jour. de Phys.* vol. liii. (b.) Steel, Stodart on Tempering, *Nich. Jour.* 4to. vol. iv.; Davy, *An. Phil.* vol. i.; Pearson, *Phil. Trans.* 1791; Scheele on Plumbago, *Essays*; M'Kenzie, *Nich. Jour.* 4to. vol. iv.; Berzelius, *Afhandlingar*, vol. iii.; Collier, *Manchester Mem.* vol. v.; Clouet on Steel, *Jour. de Mines*, 1792, also *Jour. de Mines*, vol. iv.; Guyton and Darcet on Steel, *Jour. de Mines*, 1798; Mushet on Steel, *Phil. Mag.* vol. xii. and xiii. (c.) Bucholz, *Gehl. Jour.* vol. i. (d.) Langier, *An. de Ch.* vol. i. (e.) Berthollet, *An. de Ch.* vol. ii. (f.) Herschel, *Brewst. Jour.* vol. i. (g.) Berzelius, *An. de Ch. et de Ph.* vol. ix.

### Sect. III.—Tin.

(660.) A. Pliny begins his chapter upon Tin thus, *Stannum illud æneis vasis, saporem gratiorem facit, et compescit æruginis virus; mirumque, pondus nil angel.* (Mirum! truly.) He describes it as coming from Spain and Britain, and mentions its great abundance in the latter. (a.) Moses mentions Tin as one of the Metals that may "abide the fire" for purification. (b.) The mines of Cornwall, from which great quantities of this Metal are procured, exceed in richness those of every other part of the world; but the purest Tin is said to come from the Peninsula of Malacca. The principal ore of Tin is its oxide, under various crystalline forms, which have been ably investigated by Mr. W. Phillips. (c.) As a sulphuret it is also found, but this is a rare mineral, and largely contaminated with copper.

(661.) B. The common process for smelting Tin in Cornwall is fully described in Aikin's Dictionary; it consists in pulverizing the ore, and washing it so as to remove the lighter rocky particles. The heavy metalliferous ones which remain, are then roasted to drain off arsenic and sulphur, and to oxidate some other metallic impurities. By a subsequent washing, the oxide of Tin remains in tolerable purity; it is now mixed with charcoal, and subjected to a violent furnace heat, by which the reduction is effected, and metallic Tin subsides to the bottom of the furnace, from which it is run off into pigs for sale.

(662.) C. Tin is of a brilliant white colour; it has a slight but disagreeable taste, and emits a smell when rubbed. In hardness it is superior to lead, but inferior to gold; Specific Gravity 7.291 to 7.299. "It is very malleable: Tin-foil, as it is called, is about one-thousandth of an inch thick, and it might be beaten out into leaves as thin again if wanted for purposes of Art. Its ductility and tenacity are much inferior to that of most of the Metals known to the Ancients." A wire one-tenth of an inch in diameter is calculated just to support a weight of 47.36 pounds. Tin is very flexible, and a singular crackling noise is heard on bending it; the property is peculiar to this Metal and cadmium. Tin fuses at a temperature of 442° Fahrenheit, but requires a very high temperature for its volatilization. By careful cooling, the crystals obtained from this Metal are rhomboidal prisms (d.)

(663.) D. By exposure to air Tin becomes tarnished, but undergoes no further change; at ordinary temperatures it has no action upon water, but if steam is passed over Tin heated to redness, a rapid decomposition

is effected, the Tin is oxidated, and hydrogen is given out. (e.) Of this Metal there are two distinct oxides. The first, or grey oxide, is produced by dissolving Tin in hydrochloric Acid, with aid of heat, and precipitating the solution by ammonia. Thus an hydrate of the protoxide is obtained. By heat it is not decomposed, but passes to a higher degree of oxidation; it is soluble in alkalis and Acids.

The deutoxide is obtained by acting upon Tin with concentrated nitric Acid; no solution is effected, but a white powder is formed, which is a hydrate of the deutoxide. By heat, the water is driven off, and the pure yellow deutoxide remains. Berzelius obtained the same substance by heating Tin filings in contact with peroxide of mercury. (f.)

This oxide may, by digestion, be united to the sulphuric and muriatic Acids; but though in both cases the compound remains insoluble in the Acid, yet in the former it becomes soluble in water. In the same manner, by digestion with alkalis, compounds soluble in water are similarly produced.

The two oxides of Tin are easily distinguished from each other by their properties: the protoxide undergoes evident combustion, at a red-heat; the deutoxide does not so. The former is soluble in dilute nitric Acid; the latter is not so. The former deflagrates with nitre; the latter does not so. Solutions of the protoxide gives black precipitates with corrosive sublimate.

(664.) E. Two chlorides of Tin are described by Dr. J. Davy. (f.) The protochloride is most easily obtained by heating protomuriate of Tin in a retort, till a fused, grey, resinous substance remains.

The deutochloride may be formed by heating Tin, or its protochloride, in chlorine Gas; but it is most readily formed by heating 6 parts of Tin, 1 of mercury, and 33 of corrosive sublimate, together in a retort. At first, water is disengaged, but afterwards a white vapour is rapidly produced, and condensed in a receiver, forming a colourless Liquid. This has long been known by the name of the *fuming liquor of Libavius*, from its discoverer.

(665.) F. Unexamined.

(666.) G. Tin in fusion readily combines with the vapour of iodine, and a fusible, orange-coloured iodide is the result. Water converts it into hydriodic Acid and oxide of Tin.

(667.) H. Tin, in all probability, does not combine with hydrogen nor azote; neither has its union with carbon, boron, or silicon been effected. The phosphuret may be formed by dropping pieces of phosphorus into melted Tin, or by fusing in a crucible equal parts of glacial phosphoric Acid and Tin-filings.

Three sulphurets of Tin are known to Chemists. The proto-sulphuret is formed by fusing Tin and sulphur together, pulverizing the compound, again mixing it with sulphur, and subjecting it to a sufficient heat to volatilize all the superabundant sulphur. This compound has metallic lustre with the colour of lead, and is capable of crystallization. "When dissolved in concentrated muriatic Acid it is entirely converted into oxide of Tin and sulphuretted hydrogen Gas." Thomson.

A substance, long known to Chemists under the name of *Aurum Mosaicum*, is the deuto-sulphuret of this Metal. The best process for obtaining it appears to be as follows. Amalgamate 8 oz. of Tin with an equal quantity of mercury, mix this with 6 oz. of sulphur and 4 of muriate of ammonia. Expose this compound to a violent



Chemistry. heat in a matrass, and on breaking the matrass, beautiful hexagonal plates of the *aurum mosaicum* will be found condensed within the neck of the vessel. This substance is in the form of delicate scales, which have the appearance of gold, and if applied with varnish to any smooth surface, may be made to acquire considerable beauty from the operation of the burnisher.

The other sulphuret of Tin was obtained by Berzelius, who distilled deutosulphuret of Tin with sulphur; and obtained what has been called a sesquisulphuret, but is in our nomenclature a hemideutosulphuret of Tin.

(668.) I. Tin appears, as far as trial has been made, to be capable of uniting with every Metal; producing greater or less change in their mutual properties. With potassium, sodium, cobalt, arsenic, brittle alloys are formed. With bismuth, zinc, and lead, the alloys have considerable ductility and tenacity. Iron does not combine readily with Tin, but by fusing the Metals, in a closed crucible, an alloy is formed. According to Bergman (*h.*) two distinct alloys, containing widely different proportions of the Metals, are found after fusion in the same crucible, the one of 21 Tin + 1 iron, the other of 1 Tin + 2 iron; this is a question worthy of examination.

(669.) K. The Salts formed by the oxides of Tin are exceedingly curious, and have important properties.

Diluted nitric Acid (Specific Gravity 1.114) dissolves Tin with effervescence, and it is recommended to moderate the violence of the action by plunging the vessel in which the process is carried on into cold water. Thus a solution of protonitrate of Tin is obtained. By standing, and especially if heat be applied, a portion of the protoxide is deposited; the solution also contains nitrate of ammonia, for in the process both nitric Acid and water are decomposed, and by the union of the nascent azote of the one, and the hydrogen of the other, the alkali is generated.

If, however, strong nitric Acid (Specific Gravity 1.25) be poured upon Tin-filings, the action is exceedingly violent, and the Metal being oxidated *ad maximum*, is entirely precipitated in the state of a white powder; thus pernitrate of Tin cannot exist. In this case, also, ammonia is produced. This interesting experiment may be performed by adding a small quantity of strong nitric Acid to Tin-foil, or Tin-filings, in a Wedgewood mortar, and after the first violence of the action has ceased, and the fumes of nitrous Gas are chiefly dispersed, add a little caustic alkali or quick-lime; on rubbing the mixture together a pungent smell from the disengaged ammonia is perceptible.

By the action of cold sulphuric Acid on this Metal, the Acid is decomposed, sulphurous Acid Gas is evolved, and a persulphate of Tin is fully held in solution; by evaporation, this Salt gelatinizes, but does not crystallize; and by affusion of water, it is separated in the form of a white powder.

By solution of the protoxide of Tin in this Acid, a crystalline protosulphate may be formed.

If a plate of Tin be placed in sulphurous Acid, a black powder gradually falls, which is sulphuret of Tin, produced by the partial decomposition of the Acid; while at the same time a part of the Tin is oxidated, and hyposulphite of Tin remains in solution. According to Herschel, also, this hyposulphite is a soluble Salt, as mere Tin causes no precipitate in an alkaline hyposulphite.

Hydrochloric Acid readily dissolves Tin, with evolution of a fetid hydrogen Gas. In this solution the Metal is in the state of protoxide, and from the strong tendency which Tin has to pass to the higher degree of oxidation, this solution produces marked effects in many metallic solutions, wherein the oxygen is combined with the Metal by a feeble degree of affinity. Thus by protohydrochlorate of Tin, solutions of zinc, antimony, silver, and mercury, are precipitated in the metallic state, either pure or mixed with some portion of Tin. With gold a purple precipitate is produced, containing both gold and Tin in some state of combination, not at present clearly understood. The persalts of iron are reduced to the state of protosalts. For many more of these important properties we must refer to the Memoirs of Pelletier and Proust. This protohydrochlorate may be crystallized, but readily changes to the state of deutohydrochlorate, if great care be not taken to preserve it from oxygen. The deutohydrochlorate may be formed by dissolving the deutoxide of Tin in muriatic Acid, or by the process before given for obtaining Libavius's liquor, in which state it has been already described.

From the failures of Bergman (*i.*) and Proust (*k.*) it would appear that no carbonate of Tin can exist.

Phosphate of Tin being insoluble in water, is formed by adding hydrochlorate of Tin to an alkaline phosphate, but liquid phosphoric Acid has scarcely any action on metallic Tin.

Precisely similar properties mark the action of boracic Acid. Arsenic Acid is slowly decomposed if digested upon Tin; but by adding this Acid to acetate of Tin, or by mixing alkaline arseniates with muriate of Tin, an insoluble arseniate of Tin is precipitated.

With the assistance of heat, acetic Acid acts slowly upon Tin; and both the protacetate and deutacetate seem to have been formed; the first capable of crystallization; the second only capable of gelatinization.

Benzoic Acid does not dissolve Tin or its oxides, but by adding benzoate of potash to a solution of Tin a benzoate of Tin is precipitated. It is soluble in hot water, but insoluble in alcohol.

Succinate of Tin is a crystalline Salt in tables, produced by dissolving the oxide in the Acid and slow evaporation.

By the aid of heat, oxalic Acid first blackens Tin, and then incrusts its surface with a white oxide, of which a portion is taken up. Prismatic crystals may be obtained by slow evaporation.

Tartrate of Tin is formed by dissolving the metallic oxide in tartaric Acid. By boiling oxide of Tin in a solution of tartrate of potash, a very soluble, but crystallizable, double Salt is formed, from which the alkalis and their carbonates produce no precipitate. (*m.*)

Deutoxide of Tin appears also to dissolve in nitrate of ammonia, producing a double Salt in solution. (*l.*)

(670.) L. The effects of reagents upon solutions of Tin are as follows. Gallic Acid and infusion of galls, no precipitate. Prussiate of potash, a white one. Hydrosulphuret of potash, a dark brown one in Salts of the protoxide, and a deep yellow precipitate in those of the deutoxide. Corrosive sublimate produces in the former Salts black, in the latter white precipitates. Lead precipitates Tin from some of its Salts in the metallic state. With the protosalts a solution of gold produces a purple precipitate.

(671.) M. Tin is of importance in the Arts for the

**Chemistry.** formation of several alloys. The bronze of the Ancients, a very beautiful compound, sufficiently hard for the formation of swords and spear-heads, consisted of 88 parts of copper and 12 of Tin. Gun-metal is of about the same composition. (n.) (o.) In bell-metal the Tin is from one-fifth to one-third of the weight of the copper. The Chinese gong is formed of 80 of copper and 20 of Tin. (p.) For the specula of telescopes, Mudge recommends 1 part of Tin to 2 of copper; but Mr. Edwards's experiments are in favour of a more complex material, consisting of 32 of copper, 15 or 16 of Tin, with brass, arsenic, and silver, each 1 part. (q.) The surface of copper-vessels for culinary purposes is often covered with a film of Tin, to prevent the poisonous effects produced by solution of the former Metal. The process is extremely simple: the copper being first polished, and then covered with a coating of sal ammoniac or pitch, to prevent oxidation, and the vessel being heated, the Tin is applied hot, and readily adheres to the surface of the copper. On similar principles the manufacture of Tin-plate is effected; thin sheets of polished iron are dipped into a vat of melted Tin, having a coat of tallow floating upon its surface. The Tin unites with the surfaces of the iron forming with it an alloy to a slight depth. Pewter is of very variable composition, but most is formed from Tin and lead; the best, however, contains only Tin with a little antimony. This compound may safely be used even for vinegar; for unless the lead be in improper excess, none of it is taken up by the Acid; but if any solution takes place, it is only of a small quantity of Tin. Nitric Acid, on the contrary, takes up more of the lead than of Tin. Plumbers' solder contains equal parts of Tin and lead. In silvering mirrors, Tin-foil is spread on flat stones, and then covered with quicksilver; the glass is then so applied as to remove as much as possible of the mercury, and the remaining amalgam adheres to the surface of the glass. The oxides of Tin are the principal basis of white enamel; and some of its Salts are of great use as mordants in dyeing. (r.)

References to § 3.

(a.) *Hist. Nat.* ch. xvi. lib. xxxiv. (b.) No. xxxi. p. 22. (c.) *Geo. Trans.* vol. i. (d.) Pajot, *Jour. de Phys.* vol. xxviii. (e.) Gay Lussac, *An. de Ch.* vol. lxxx. (f.) *Nich. Jour.* vol. xxxv. (g.) *Phil. Trans.* 1812. (h.) *Opusc.* vii. iii. p. 471. (i.) *Opusc.* vol. ii. (k.) *Jour. de Phys.* vol. li. (l.) Thenard, *An. de Ch.* vol. xlii. (m.) Thenard, *An. de Ch.* vol. xxxviii. (n.) Pearson, *Phil. Trans.* 1796. (o.) Dizé, *Jour. de Phys.* 1790. (p.) Thomson, *An. Phil.* vol. ii. (q.) Mudge, *Nich. Jour.* vol. iii. and Little, *Nich. Jour.* vol. xvi. (r.) Mode of Making Tin Plate, Watson, *Essays*, vol. ix. and Parkes, *Mech. Mem.* N. S. vol. iii.; Proust, *Nich. Jour.* vol. xiv.; Pelletier, *Mém. de Ch.* tom. i. and ii.

Sect. IV.—Zinc.

(672.) A. Metallic Zinc was unknown to the Ancients, though they were well acquainted with its ore, and used it largely in the formation of brass. Owing to its volatile nature and strong affinity for oxygen they never obtained it in the reduced form, though its oxide formed some of their medicinal preparations. Pliny says, *Plura autem genera sunt, namque ipse lapis ex quo fit æs, cadmia vocatur.* (a.) Henckel first mentions its reduction in 1721. Zinc has never been found in

the metallic state, but exists abundantly as a sulphuret and carbonate: sometimes also combined with oxygen and silica.

(673.) B. The reduction of Zinc is performed on a large scale in Britain, principally from the sulphuret; the ore is roasted, and then reduced to powder, mixed with charcoal, and violently heated in earthen melting-pots. It either passes in fusion through an iron tube from the bottom of these crucibles, or is volatilized; and in both cases, the tube terminating in a vessel of water, the Metal is condensed, and subsequently fused into convenient masses for market. (b.)

To obtain pure Zinc for Chemical purposes, let the Metal be dissolved in sulphuric Acid to saturation, leaving a plate of the Metal a short time in the solution, by which all impurity of foreign Metals will be precipitated. Decompose the filtered solution by an alkaline carbonate, and reduce the powder produced; by mixing it with half its weight of charcoal, and submitting it to a strong heat in a retort, the pure Zinc will condense in the beak of the vessel, which is to be kept cool.

(674.) C. Zinc is of a bluish-white colour, of a laminated structure, and fine granular fracture, Specific Gravity 6.8 to 7.1, more malleable than antimony, but less so than copper or lead; rather ductile, but at ordinary temperatures not very elastic. At a temperature from 212° to 310° it becomes very malleable, and may be formed into thin sheets by passing it between steel rollers; at 400° it becomes again quite brittle, and may be pulverized, and at about 180° Fahrenheit it fuses (Black.) By higher temperatures it is capable of distillation in close vessels.

(675.) D. Though the surface of Zinc becomes tarnished, it can scarcely be said to undergo oxidation by exposure to the air. At ordinary temperatures it very slowly decomposes water; but if watery vapour be passed over Zinc made red hot, a most rapid decomposition is effected, the Metal becomes oxidated, and hydrogen is evolved. If Zinc be fused in an open vessel, it forms a greyish oxide. But if an earthen crucible be heated red hot, and small pieces of Zinc be projected into it, a most intense white light marks rapid combustion, and an abundance of white flakes are carried up by the current of heated air. This delicate white powder, the *nil album*, *lana philosophica* of the Alchemists, Flowers of Zinc of the early medical writers, is the pure white oxide of this Metal. This substance is not volatile, and very difficult of fusion; insoluble in water, it absorbs carbonic Acid from the atmosphere, is not decomposed by heat, but reducible by the Voltaic pile; and by heat, if in contact with charcoal, the Metal distils over in closed vessels. It is the only oxide which Chemists have been able to procure from this Metal.

(676.) E. Zinc readily takes fire in chlorine Gas, and a chloride of Zinc is formed. By evaporating a solution of hydrochlorate of Zinc to dryness, and subsequent exposure to a red heat in a glass tube with a minute orifice, the same substance is produced. In this state, according to Dr. John Davy, (c.) it is not capable of being sublimed by a low red heat.

(677.) F. Zinc is soluble in fluoric Acid, and it seems very probable that by exposure to heat the Salt so formed would be converted into a fluoride of Zinc.

(678.) G. If iodine and Zinc be fused together, iodide of Zinc is formed. It is a volatile compound, which on condensation crystallizes in small quadrangular prisms, which deliquesce by exposure to air, and are

Chemistry soluble in water. In this state it becomes, in fact, a solution of hydriodate of Zinc.

(679.) H. Zinc unites with phosphorus, forming a metallic-looking compound. The sulphuret of this Metal cannot be directly formed by melting the two substances together, but if, instead of metallic Zinc, its oxide is fused with sulphur, a true sulphuret is formed. The same substance is precipitated by dropping an alkali hydrosulphuret into a solution of Zinc. According to Mr. E. Davy, if the vapour of sulphur is passed over Zinc in fusion, a yellowish compound, similar to blende, is produced. The properties of Zinc and selenium are precisely similar to those just described. Direct union is impossible, but when volatilized selenium comes in contact with fused Zinc red-hot, an instantaneous combination takes place with such violence, as to produce a sort of detonation. (d.) Zinc has not been united to boron or silicon, and it is stated not to combine with hydrogen or azote. It must, however, be remembered that most Chemists are of opinion, that in the common process of obtaining hydrogen by the action of sulphuric Acid and Zinc upon water, some portion of the Metal is carried up along with the Gas.

(680.) I. Zinc has been alloyed with potassium, sodium, (c.) iron, antimony, copper, gold, silver, lead, tin, and mercury. It is said that it refuses to unite with nickel and cobalt.

(681.) K. Nitric Acid readily dissolves Zinc or its oxide; and in operating upon the Metal it is advisable to moderate the action, by using the Acid in a dilute state. By evaporation, this nitrate is said to crystallize in "flat, striated, tetrahedral prisms, terminated by four-sided pyramids." These crystals are soluble in water and alcohol. They are entirely decomposed by a sufficient heat.

Concentrated sulphuric Acid has little action upon Zinc without heat, but if diluted, dissolves it with rapidity. By evaporation, the sulphate of Zinc crystallizes in four sided, rectangular prisms, terminated by tetrahedral pyramids. In this state it is the *white vitriol* of Commerce. By a strong and continued heat, it is entirely decomposed, leaving oxide of Zinc in great purity.

Sulphurous Acid dissolves oxide of Zinc, forming a crystallizable sulphite which is not soluble in alcohol.

On metallic Zinc, sulphurous Acid exerts a considerable violence of action, and hydrosulphuric Acid Gas is given out, the water undergoes an entire, and the Acid a partial, decomposition; oxygen goes to the Zinc, and part of the sulphur escapes in combination with the hydrogen; thus the Acid becomes the hyposulphurous, and being neutralized by the oxide, hyposulphite of Zinc remains. By spontaneous evaporation, slender, four-sided crystals, with pyramidal summits, are produced. These are soluble in water and alcohol. (Fourcroy.)

The carbonate of Zinc occurs native, and is known by the name *calamine*; it exists both as an hydrous and as an anhydrous Salt. A solution of carbonic Acid dissolves both Zinc and its oxide, but the carbonate is more readily formed by adding an alkaline carbonate to a solution of Zinc. The Salt precipitates in the form of a white powder; but is again dissolved by excess of the precipitating Acid.

Borate of soda in solution, added to sulphate of Zinc in the same state, throws down a white powder, consisting of borate of Zinc, which heat fuses, but does not decompose.

Phosphoric Acid dissolves Zinc, but ceases to act when the Salt has arrived at the state of a biphosphate, which may be evaporated just to dryness without crystallization or decomposition. If, however, such a saturated solution be boiled upon carbonate of Zinc, a true insoluble phosphate of Zinc is formed.

Berzelius has described the seleniate and biseleniate of Zinc; (f.) the former is insoluble, the latter soluble in water.

The arseniate, antimoniate, tungstate, molybdate, and chromate of Zinc, are formed by adding their alkaline Salts to a solution of sulphate of Zinc; in all cases a white, insoluble powder is precipitated, the chromate excepted, which is of an orange-red colour.

Acetic Acid dissolves Zinc; and by evaporation a crystalline acetate is obtained, readily soluble in water.

The benzoic, succinic, malic, and lactic Acids, dissolve Zinc, and form crystallizable Salts, which are again soluble in water.

The oxalic, citric, and tartaric Acids also attack Zinc, but the Salts which are thus formed, immediately separate from being insoluble in water.

A double tartrate of potash and Zinc may be formed by boiling tartaric Acid and Zinc filings in water. (g.) A double sulphate of Zinc and iron is formed by mixing a solution of sulphate of iron with that of sulphate of Zinc; the Salt is soluble, and may be obtained in crystals by evaporation. Sulphate of Zinc and cobalt may be formed by digesting zaffre in a solution of sulphate of Zinc. It crystallizes in large, four-sided prisms. (h.)

A mineral substance, known by the name of electric calamine, consists of silica and oxide of Zinc; and here the former substance is considered to perform the part of an Acid; it is therefore called silicate of Zinc. The crystalline forms are numerous; a small hexagonal prism or an acute octahedron is the most common.

Caustic ammonia is capable of dissolving the oxide of Zinc, and has even some action on the Metal; after which a mass of plumose crystals may be obtained by evaporation. From such a solution copper precipitates Zinc; but Zinc precipitates copper from an Acid. May not this tend to prove that the oxide of Zinc here acts the part of an Acid?

(682.) L. Many of the instances in which saline solutions form reagents for the separation of Zinc, may be collected from the preceding section. Its Salts, when in solution, are always colourless. Alkalis produce a white precipitate, soluble in sulphuric or hydrochloric Acid. Prussiate of potash, hydriodate of potash, hydrosulphate of potash, and hydrosulphuric Acid Gas, produce white precipitates. Gallic Acid and infusion of galls give no precipitate. Zinc is not thrown down in the metallic state from its solution by any other Metal.

(683.) M. The sulphate of Zinc is used as an emetic, and the acetate has recently been recommended by Dr. Henry as an external application to remove inflammation. It has long formed a constituent of some empiric eye-waters.

Zinc is principally obtained on the large scale for the formation of brass. This useful and beautiful alloy commonly consists of about 62 to 66 of copper, with from 32 to 35 of Zinc; (Chaudet;) the more valuable kind, known by the name of Dutch brass, was found by Thomson to contain 70 of copper and 30 of Zinc, but he considers that much of its superiority consists in the greater purity of the Metals, which in common brass

Chemistry. are contaminated with lead. (i.) When the copper is in greater proportion, other Metals are formed, known in Commerce by the names of pinchbeck, Prince's metal, &c. A considerable quantity of Zinc is employed for the plates of galvanic batteries. Its white oxide forms a pure and delicate white paint. Recently it has been much employed for making the shoots carried round the eaves of houses to collect rain-water.

References to § 4.

(a.) *Hist. Nat.* ch. xxxiv. sec. 10. (b.) Watson, *Essays*, vol. iv. (c.) *Phil. Trans.* 1812. (d.) Berzelius, *An. de Ch. et Ph.* vol. x. (e.) Gay Lussac and Thenard, *Recherches*. (f.) *An. de Ch. et Ph.* vol. ix. (g.) Thenard, *An. de Ch.* vol. xxxviii. (h.) Link, *Crell's Annals*, 1796. (i.) *An. Phil.* vol. xii.

Sect. V.—Cadmium.

(684.) A. In the year 1817, Professor Stromeyer of Gottingen discovered the oxide of a peculiar Metal as an impurity in oxide of zinc, sold for medicinal purposes; while at the same time a peculiarity in a preparation of zinc, from the manufactory of M. Hermann in Silesia, led to the observation of the same metallic oxide. The oxide of zinc had been condemned on the supposition that it contained arsenic, because it produced an orange precipitate with hydrosulphuric Acid Gas. On more accurate investigation, this suspicion was found to be without foundation; and some of the orange precipitate having been transmitted to Stromeyer, he recognised in it the same metallic oxide, to the Metal from which he gave the name of Cadmium. (a.) This Metal has since been found in some of the English ores of zinc by Professor Clarke of Cambridge; (b.) but its most abundant ore is the brown fibrous blende of Bohemia. Mr. Herapath has pointed out an abundance of the oxide also in the sublimate from zinc furnaces. (c.)

(685.) B. Stromeyer's process for obtaining the Metal is as follows. A solution of the ore or oxide is made in sulphuric Acid, by passing a current of hydrosulphuric Acid Gas through the Liquid; the Cadmium, zinc, and copper, if present, are precipitated. Redissolve in concentrated hydrochloric Acid, and evaporate to dryness, to get rid of the excess of Acid. Dissolve in water, and add excess of carbonate of ammonia, by which the zinc and copper are dissolved, but the carbonate of Cadmium remains in the state of a fine white powder. At a red heat the Acid is driven off, and oxide of Cadmium remains. This oxide may be reduced to the metallic state by mixing it with lamp-black, and exposure to a low red heat in a glass tube or small retort.

The following elegant process for obtaining Cadmium is from Dr. Wollaston. From the solution of the ore, precipitate all other metallic impurities by a plate of iron; filter, and immerse a plate of zinc in the clear solution: if Cadmium be present, it will be precipitated in the metallic state, and may be redissolved in hydrochloric Acid, for the exhibition of appropriate tests.

(686.) C. Cadmium is of a bluish-white colour, and, much like tin, susceptible of a fine polish. Its texture is compact, and Specific Gravity 8,604—8,694. It fuses, and is volatilized below a red heat; in fact, at a heat rather above that of boiling mercury. It crystallizes in octohedra, is flexible, and gives, on bending, the

same sound as tin does. It is ductile and malleable, yielding readily to the knife; but exceeds tin in hardness and tenacity.

(687.) D. When Cadmium is heated with access of air, it burns, and the smoke condenses in the form of a brown powder, its only known oxide. In this state it is readily soluble in nitric Acid, and feebly so in dilute hydrochloric, sulphuric, and acetic Acids. Oxide of Cadmium is soluble in ammonia, but not in the fixed alkalis.

(688.) E. If oxide of Cadmium be dissolved in hydrochloric Acid, small rectangular crystals of hydrochlorate of Cadmium are obtained by evaporation. By heat these are converted into chloride of Cadmium, and are even capable of volatilization unaltered.

(689.) F. Unknown

(690.) G. Iodine and Cadmium, if heated together, readily unite. Or if water be boiled upon the two substances in contact, a solution is obtained, which by evaporation may be crystallized in the form of hexagonal plates. These crystals are decomposed by heat, and are soluble in water and alcohol.

(691.) H. The combinations which ought to fall under this head are at present little investigated. Cadmium and sulphur do not unite readily by fusion, but the sulphuret is easily formed by passing a current of hydrosulphuric Acid Gas through a solution of a Salt of Cadmium. The yellow sulphuret thus produced, forms, according to Stromeyer, an excellent paint. By the action of nitric Acid, the sulphuret is converted into a neutral sulphate. The phosphuret of Cadmium is a grey, metallic-looking, brittle substance, easily fusible; placed on burning coals it ignites, and is converted into the phosphate.

(692.) I. As yet Cadmium has been alloyed only with copper, mercury, cobalt, platinum, and zinc.

(693.) K. The Salts of Cadmium are at present little known. The nitrate, sulphate, and acetate are soluble in water. The carbonate, phosphate, and oxalate are insoluble in water. The borate, tartrate, and citrate are very slightly soluble.

(694.) L. In solutions of Cadmium the fixed alkalis produce permanent precipitates, but ammonia produces a precipitate which excess of the alkali again dissolves. "The alkaline carbonates throw down Cadmium in the state of a white carbonate. This carbonate does not form an hydrate, as is the case with carbonate of zinc. Neither is it redissolved by adding excess of carbonate of ammonia, as is the case with carbonate of zinc, unless there previously existed a notable excess of Acid in the solution."

"Phosphate of soda throws down Cadmium in the state of a white powder, zinc in the state of crystalline scales." Thomson.

Hydrosulphuric Acid Gas and the hydrosulphurets produce a yellow precipitate, easily soluble in hydrochloric Acid, and unaltered by a low red heat; in which two points it differs from orpiment.

Prussiate of potassa precipitates solution of Cadmium white.

Infusion of galls gives no precipitate.

Cadmium is precipitated by zinc in the metallic state.

(695.) M. None at present.

References to § 5.

(a.) Stromeyer, *An. Phil.* vol. xiii.; Gilbert, *Annalen*, vol. lx.; *An. Phil.* vol. xiv. p. 269. (b.) Clarke,

Chemistry. *An. Phil.* vol. xv. p. 272. (c.) Herapath, *An. Phil.* N. S. vol. iii. p. 435.

## METALS. CLASS IV

### Sect. I.—Arsenic.

(696.) A. "The word Arsenic (*ἀρσενικόν*) occurs first in the Works of Dioscorides, and some authors who wrote about the beginning of the Christian era. It denotes in their Works the same substance which Aristotle had called *σανδαράχη*; and his disciple Theophrastus *ἀρσενικόν*, which is a reddish-coloured mineral, composed of Arsenic and sulphur, used by the Ancients in painting, and as a medicine. (a.)

"The white oxide of Arsenic, or what is known in Commerce by the name of Arsenic, is mentioned by Avicenna, in the XIth century; but at what period the Metal called Arsenic was first extracted from that oxide is unknown. Paracelsus seems to have known it; and a process for obtaining it is described by Schroeder in his *Pharmacopœia*, published in 1649. But it was only in the year 1733, that this Metal was examined with Chemical precision. This examination, which was performed by Mr. Brandt, (b.) demonstrated its peculiar nature; and since that time it has been always considered as a distinct Metal, to which the term *Arsenic* has been appropriated. Its properties were still further investigated by Macquer, in 1746, (c.) by Monnet, in 1773, (d.) by Bergman, in 1777. (e.) To the labours of these Philosophers, and those of Mr. Scheele, (f.) we are indebted for almost every thing known about the properties of this Metal. Its combinations with oxygen have been carefully examined by Proust, (g.) Bucholz, (h.) Berzelius, (i.) and some other Chemists." (k.) Thomson. (l.)

Arsenic exists native, in the state of an oxide; and as a constituent part of many metalliferous ores.

(697.) B. To obtain metallic Arsenic, let the white oxide of Commerce be mixed with half its weight of black flux; (made by deflagrating two parts of crystals of tartar with one part of nitre in a crucible.) Put the mixture into a crucible; invert over this another crucible, and let the two be luted together with sand and clay. Expose the lower crucible to a red heat, and let the upper one be kept as cool as possible. Brilliant metallic Arsenic will be found sublimed into the upper crucible. A wide earthen tube-retort, divided into two parts, would be more convenient.

(698.) C. Arsenic is so brittle and soft that it may easily be pulverized. It is readily fusible, and rises in vapour at about 356° Fahrenheit. When thrown on a red-hot iron, it burns with a blue flame and a white smoke, having a strong alliaceous odour. This odour is not present when only the oxides of Arsenic are volatilized.

(699.) D. If Arsenic be moderately heated with free access of atmospheric air, sublimation takes place, and a white powder is condensed, which is Arsenious Acid. See subject 1.

Besides this oxide another exists having also acid properties. This was discovered by Scheele; and the process recommended by Bucholz for obtaining it is as follows: Mix two parts of hydrochloric Acid, Specific Gravity 1.2; eight parts of Arsenious Acid; and twenty-four parts of nitric Acid. (Specific Gravity 1.25.) Evaporate the mixture to dryness, giving at last a low

red heat. (m.) The same Acid is still more readily obtained by dissolving Arsenic in nitric Acid, and evaporating to dryness. See subject 2.

As far as at present known, the following is the composition of these two oxides:

	Arsenic.	Oxygen.
Arsenious Acid . . . . .	one atom	+ two atoms.
Arsenic Acid . . . . .	one atom	+ three atoms.

In this and all such cases it is surely more easy to speak of the deutoxide and tritoxide of Arsenic, and to remember that the protoxide has not yet been exhibited; than it is to speak of the protoxide, and to remember that it contains an atom more oxygen than protoxides in general; and of the deutoxide, having also to remember that it is similarly circumstanced.

(700.) E. Arsenic undergoes combustion in chlorine Gas, and a true chloride of Arsenic is formed. It is most fully described by Dr. Davy. (n.)

(701.) F. Unknown.

(702.) G. Iodine and Arsenic unite to form a deep red iodide, which is capable of decomposing water and affords Arsenic and hydriodic Acids.

(703.) H. Arsenic unites with hydrogen to form a gaseous substance; (o.) but there is considerable danger in making experiments upon it, as the mere inhaling a small quantity killed M. Gehlen. (p.)

Arsenic unites with sulphur in two proportions, and both compounds are found native: these are realgar and orpiment. (q.) It combines also with phosphorus and selenium.

(704.) I. This Metal combines to form alloys with all the other Metals; and has even in very small quantity the property of rendering them quite brittle.

(705.) K. The oxides of Arsenic seem to possess little power of performing the parts of a base in the formation of Salts. The sulphate, borate, phosphate, nitrate, and hydrochlorate of Arsenic, have been described. In these Salts, the Acid and base are held by very feeble affinities.

But the oxides of Arsenic are capable of more important effects in performing the part of Acids with certain bases; and hence has been called Arsenious and Arsenic Acids.

(706.) L. In Medical Jurisprudence, a decisive test of Arsenic is a matter of great importance; as upon it the life of an accused person must frequently depend. Several tests have been proposed for this purpose, but, as it would seem, all are more or less uncertain. For an able investigation of this point we are indebted to Dr. Christison; and from his *Memoirs* we give the following summary of what he considers a faultless process for the purpose. Let the mass of fluids suspected of containing Arsenic, suppose for instance the contents of the stomach of a deceased person, be well agitated and boiled with water, and thrown on a filter. Be careful to acidulate the clear Liquid with hydrochloric or acetic Acid. Through this Liquid pass a current of hydrosulphuric Acid Gas, (sulphuretted hydrogen.) Suppose a yellow precipitate to be formed. It may be the sulphurets of Arsenic, cadmium, tin, antimony, or selenium. But the sulphuret of Arsenic will easily be recognised by the following properties. Let a portion of it be dried; mixed with a little black flux, (697.) placed in a dry glass-tube, and raised to a red heat in the flame of a spirit-lamp. The Arsenic is reduced, rises in vapour,

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and is condensed in the form of a bright iron-grey crust lining the cooler part of the tube. The inner surface presents also a crystalline appearance. By vaporizing a little of this Metal, the alliaceous odour of garlic is instantly perceptible. This evidence is quite conclusive. But it is easy also to reconvert the Metal into Arsenious Acid. For this purpose hold the part of the tube to which the Arsenic adheres about three-fourths of an inch above the flame of a very small spirit-lamp, so that the Metal may rise in vapour very gradually. In so doing it combines with oxygen, and is deposited in well-characterized crystals of Arsenious Acid, on the cooler parts of the tube. It is essential that the tube be quite dry. The volatility, form, transparency, and adamantine lustre are so characteristic, that Dr. Christison considers that one-hundredth of a grain is sufficient to satisfy an experienced eye. This gentleman states that he has been able by these processes to separate and exhibit in two instances so small a quantity as the twentieth of a grain from the stomachs of people who had been poisoned with Arsenic. (r.)

(707.) M. Arsenic, in the form of its yellow sulphuret, forms a pigment, being the colouring principle of *King's yellow*. The sulphurets of Arsenic are poisonous, but not to such an extent as the Metal or its oxides. Preparations of Arsenic have been employed in Medicine, and form the active ingredient in Fowler's *Ague-drops*.

*Subsect. 1.—Arsenious Acid.*

(708.) Having previously stated the formation and constitution of Arsenious Acid, (699.) we may here note a few of its principal properties, though in so doing we must be as brief as possible. According to Klaproth and Bucholz, cold water dissolves only .25 per cent. of its own weight of white Arsenic; whilst boiling water takes up 7.775 per cent. A part was again deposited on cooling, but 4.775 per cent. remained in solution. This oxide is soluble also in alcohol and oils. Arsenious Acid is capable of neutralizing the alkaline bases; and thus forms a class of Salts called *Arsenites*. It unites in a similar manner with several metallic oxides.

*Subsect. 2.—Arsenic Acid.*

(709.) The formation of this Acid has been noticed in Art. 699. It reddens vegetable blues; attracts moisture from the atmosphere; effervesces strongly with solutions of alkaline carbonates. By evaporation it gelatinizes, but does not crystallize. It unites also with bases, forming a class of Salts called *Arsenates*.

References to § 1.

(a.) *Hist. Nat.* lib. xxxiv. ch. xviii., and consult Salmasius in *Solius* p. 1154. (b.) *Mem. Phil. Soc. Upsala*, 1733, p. 39. (c.) *Mem. Par.* 1746, p. 223; and 1748, p. 35. (d.) *Sur l'Arsenic*. (e.) *Opusc.* vol. ii. p. 272. (f.) *Essays*, vol. i. p. 129. (g.) *Jour. de Phys.* 1799, p. 151. (h.) *Jour. de Chim.* vol. iv. p. 5. (i.) *An. de Ch.* vol. lxxx. p. 9. (k.) *An. Philos.* vol. iv. p. 171. (l.) *Syst.* vol. i. p. 305. (m.) Van Mons, *Jour. de Ch.* vol. iv. p. 16. (n.) *Phil. Trans.* 1812, p. 186. (o.) *Jour. Roy. Inst.* vol. xiii. p. 225. (p.) *An. de Ch.* vol. xcv. p. 110; and *An. de Ch. et de Ph.*

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vol. iii. p. 135; Strameyer, *Nich. Jour.* vol. xix. p. 381. (q) Laugier, *An. de Ch. et de Ph.* vol. v. p. 179; Berzelius, *An. Phil.* vol. xv. p. 359; Braconnot, *An. de Ch. et de Ph.* vol. xii. p. 98. (r.) *Edin. Med. and Surg. Journal*, October, 1824; and *Transactions of the Medico-Chirurgical Society*, vol. ii.

Part II.

*Sect. II.—Molybdenum.*

(710.) A. This, which is now the name of a peculiar Metal, was used by Pliny (lib. xxv. ch. xiii.) for *plumbago*, *genus herbæ*, &c. &c. *quod plumbum, id est oculorum vitium, commanducata tollit*; also, in lib. xxxiv. ch. xviii. it is explained as *vena communis plumbi et argenti*.

In 1778, Scheele analyzed this substance and obtained sulphur, and a white powder possessed of Acid properties, to which he gave the name of "Acid of Molybdena." Hjelm, in 1782, succeeded in reducing it to the metallic state; his process depended upon subjecting the oxide to intense heat after it had been mixed up with linseed-oil, but according to Bucholz, the addition of carbonaceous matter is unnecessary.

(711.) B. This Metal has hitherto resisted all efforts to reduce it to a metallic button, as the most successful experimentalists have but produced a porous mass of adhering particles.

(712.) C. Its colour is silvery-white, and the highest Specific Gravity to which Bucholz could bring it was 8.61. It appears as if under all states it would prove brittle.

(713.) D. If Molybdenum be heated in an open vessel, it undergoes oxidation, producing small, bright, needle-formed crystals, and, according to Bucholz, it is capable of forming three oxides. Mr. Hatchett is disposed to admit four.

The protoxide is said to be formed by dissolving Molybdic Acid in ammonia, and evaporating the clear solution to dryness; the residuum is exposed to a white heat with charcoal in a crucible. A brown oxide is formed at the bottom of the crucible, having a crystalline appearance, but incapable of forming Salts with Acids.

The dutoxide, or *Molybdous Acid*, (subsect. 1.) is to be formed, by mixing one part of Molybdenum with two parts of Molybdic Acid in a state of powder; the mass is to be mixed with hot water, and triturated till it becomes blue: eight or ten parts of water are added, and boiled for a few minutes. The solution is then filtered and evaporated at a temperature of 120°. The blue oxide remains in the state of a fine powder, soluble in water, which is strongly acid, converting vegetable blues to red, and saturating bases so as to form Salts.

The white oxide, or Molybdic Acid, is prepared from Molybdena, (the native sulphuret of the Metal,) by the following process of Bucholz. Expose the mineral, finely pulverized, to heat, in an open crucible, stirring it with an iron rod till the whole is of an ash-grey colour. The sulphur is driven off, and by a moderate but continued heat the Molybdenum is oxidated. It is then pulverized, and digested in a solution of ammonia in water, by which the Molybdic Acid is taken up. After this solution has remained in a close vessel to deposit its sediment, it is decanted off, and, by dropping in nitric Acid, the Molybdic Acid is precipitated in a fine white powder. See subsect. 2.

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Chemistry. (714.) E. F. G. The first of these combinations has been formed, and it is not improbable that the others may be so hereafter.

(715.) H. Molybdenum unites with phosphorus and sulphur.

(716.) I. It may be combined also with all the Metals, those only excepted the volatility of which does not allow of their being exposed to a sufficient degree of heat.

(717.) K. Both the Molybdous and Molybdic Acids are capable of neutralizing bases and forming Salts; but Salts, in which an oxide of Molybdenum serves as a base, have not been recognised: in fact, as these two higher oxides are precipitated by Acids, no such combination with them is to be expected.

(718.) L. An excellent Synoptic Table of the effect of reagents on solutions of Molybdenum is given by Professor Thomson, (a) which we regret we have not space to insert. Perhaps the most marked test is that a drop of muriatic Acid, and a piece of metallic tin, being placed in such a solution, produce a blue colour, and a blue, pulverulent precipitate.

(719.) M. None.

#### Subsect. 1.—Molybdous Acid.

(720.) For this, not very important, compound we must refer to Bucholz's Memoir. (b.)

#### Subsect. 2.—Molybdic Acid.

(721.) In a close vessel it fuses and crystallizes, but in an open one it is sublimed, and when again condensed has the form of glittering, yellow scales. It is soluble in 960 parts of boiling water, and the solution reddens litmus. The mineral Acids reproduce the white precipitate. By heat, the Molybdic Acid is soluble in sulphuric Acid, giving a colourless solution, which, however, becomes blue when cold; and this colour is increased by saturating the Acid with soda. It is also soluble in muriatic Acid, but not in the nitric. If to a muriatic solution metallic tin be added, a blue colour is produced by altering the degree of oxidation. With the nitrates of silver, mercury, and lead, white precipitates are formed; with nitrate of copper a greenish one. With neutral solutions of sulphate of zinc, muriate of bismuth, muriate of antimony, nitrate of nickel, and the muriates of gold and platinum, it gives white precipitates, according to Vauquelin. If paper be dipped in this Acid, and exposed to the light of the Sun, it assumes a beautiful blue colour.

#### References to § 2.

(a.) Thomson's *First Principles*, vol. ii. p. 58.

(b.) Bucholz, Gehlen's *Journal*, vol. iv.; consult also Scheele, *Essays*, vol. i.; Beigman, *Opusc.* vol. iii. p. 128; Pelletier, *Jour. de Ph.* 1785; Hjelm, *Crell's Annals*, 1787; Hatchett, *Phil. Trans.* 1795; Hjelm, Gehlen's *Jour.* vol. iv.; Berzelius, *An. Phil.* vol. iii.; Pelletier, *An. de Ch.* vol. xiii.; Vauquelin, *Phil. Mag.* vol. i.

#### Sect. III.—Chromium.

(722.) A. This Metal derived its name from the varied and beautiful colour of its Salts. ( $\chi\rho\omicron\mu\alpha$ , colour.)

The Siberian ore, in which it is combined with lead, was first described by Lehmann, in 1766; and, after

several inaccurate examinations, Vauquelin and Klaproth, about the same time, pronounced it to be a new Metal. Its principal ores are the beautiful Siberian red chromate of lead, from Beresof, and a dark, opaque chromate of iron. It is also considered as the colouring principle of both the ruby and the emerald.

(723.) B. The Metal is obtained by submitting the oxide, mixed with charcoal, to an intense heat. According to Richter, the charcoal from sugar answers best.

(724.) C. Chromium is white, very brittle, capable of a high polish, and, according to Richter, slightly magnetic. Specific Gravity 5.9. Fusible only at very high temperatures.

(725.) D. Chromium is not altered by exposure to the air, but if heated, it is gradually converted into a green oxide. At the three degrees of oxidation with which we are acquainted, it is green, brown, and yellow, or red; in the last state it becomes an Acid.

The green oxide may also be obtained by submitting Chromic Acid to heat, by which it is partly decomposed. When this oxide is precipitated from its solution in Acids, it is of a deep green colour, and contains water, which may be driven off by heat. In its first state it is soluble in Acids, but if subjected to a heat rather below redness, it becomes of a lighter green, and insoluble; yet without losing any of its weight.

The brown oxide may be obtained by dissolving the green oxide in nitric Acid, then evaporate and heat the dry mass until it ceases to give out nitrous fumes. A brown powder remains, which is scarcely soluble in alkalis, and not at all in Acids. If heated with hydrochloric Acid, chlorine is evolved, and the green oxide is produced; which proves that the brown powder was the Metal in a higher degree of oxidation. Chromium, in its third degree of oxidation, forms Chromic Acid, which will be found in subsect. 1.

(726.) E. If metallic Chromium be dissolved in nitro-muriatic Acid, a hydrochlorate of Chromium results; and by desiccation this is converted into a true chloride of Chromium.

(727.) F G. It is pretty well established that both these elements form Gaseous combinations with Chromium.

(728.) H. In this department few experiments have been made; but Chromium is known to unite with sulphur and phosphorus.

(729.) I. With some of the Metals Chromium has been combined, but with some it seems unwilling to unite.

(730.) K. Chromium is not soluble in the mineral Acids, the nitro-muriatic excepted. In these Acids the green oxide is soluble with difficulty. It is soluble also in the alkalis.

(731.) L. Solutions of Chromium produce a green precipitate with prussiate of Potash; a brown one with infusion of galls, and a green one with hydrosulphurate of potassa.

(732.) M. Perhaps the most beautiful fixed pigments with which we are acquainted, arise from the oxides of this Metal. In miniature-painting, the chromate of lead is highly esteemed: the oxide gives a bright green to porcelain, and imparts the same hue to the glass or paste by which the emerald is imitated. M. Lassaigue has shown that Chromium might be applied with advantage to dyeing and calico-printing. (a.) A red sulphochromate of lead, formed by Dulong, (b.) has been proposed by Mr. Badamis as a dye for cotton. (c.)



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Subsect. 1.—Chromic Acid.

(733.) Chromic Acid is obtained by the decomposition of either the chromate of lead or of iron. If the former, let it be reduced to a fine powder, and boiled in a fixed alkaline solution, which thus becomes an orange-coloured solution of the alkaline chromate. Add sulphuric Acid and evaporate. The crystals of Chromic Acid may then be separated from the alkaline sulphates. As the chromate of iron is more abundant of the two, it is generally employed for obtaining the Acid, for which the following process is employed. Let the ore be reduced to a fine powder, and mingled with an equal weight of nitre. The whole is to be submitted to a red heat for half an hour in a crucible. A yellow frit is produced, from which all the soluble part is to be removed by long boiling in water. The clear Liquid containing the chromate of potash is neutralized by nitric Acid, and then by addition of nitrate of mercury a red precipitate of chromate of mercury is produced. This precipitate is to be well washed, dried, and decomposed by heat in a retort: the mercury is driven off, and the Chromic Acid remains pure.

The Salts formed by Chromic Acid with alkaline, earthy, and metallic bases are highly interesting. All so formed from white oxides are yellow when neutral, or in the state of subsalts, and are reddish yellow when acid. Chromate of lead is yellow; of protoxide of mercury, red; of silver, purple. The chromates of the first and last four classes of Metals are decomposed at high temperatures, leaving oxide of chromium and the base. By great heat, with aid of charcoal, a perfect reduction may be obtained.

The chromates of potassa, soda, ammonia, glycena, yttria, lime, magnesia, protoxide of nickel and of cobalt, are soluble.

The insoluble chromates with their colours are barytes and strontia, white or yellow; of silver, crimson; of mercury, red; of lead, orange or yellow; of copper, apple green; of iron, brown; of uranium, zinc, and bismuth, yellow; of antimony, brown.

With solutions of nickel, zinc, tin, cobalt, gold, or platinum, no precipitate is produced.

References to § 3.

(a.) Lassaigne, *An. de Ch. et de Ph.* vol. xiv. p. 299; vol. xv. p. 76; vol. xvi. p. 400. (b.) *An. de Ch.* vol. lxxxi. p. 292. (c.) *An. Phil. N. S.* vol. ix. p. 303; consult also Vauquelin, *An. de Ch.* vol. xxv. p. 21, and p. 149, vol. xxvi.; Klaproth, *Crell's An.* 1798; also *An. de Ch.* vol. xxxii. xxxiii. xxxiv.; Moussin Pouschkin, *Crell's An.* 1798; Gmelin, *Crell's An.* 1799; Richter, *Gehlen's Jour.* vol. v.; Goden, *An. de Ch.* vol. liii.; Vauquelin, *An. de Ch.* vol. lxx.; Berzelius, *An. Phil.* vol. iii.; John, *Chemisch. Laborat.* vol. iv., or *An. Phil.* vol. iv.; Thompson, *Phil. Trans.* 1827; Unverdorben, *Edin. Jour. Sci.* No. 7.; Grouvelle, *An. de Ch. et de Ph.* vol. xvii.; Thomsou, *An. Phil.* vol. xvi.

Sect. IV.—Tungsten.

(734.) A. Scheelium, or Wolframium, the Swedish mineral Tungsten, (heavy stone,) was analyzed by Scheele in 1781, who obtained lime and a white pulverulent substance, which he considered a peculiar Acid, and which Bergman supposed to be a metallic oxide.

The D'Elhuyarts obtained it also from the mineral *Wolfram*, and succeeded in reducing it to the metallic state.

(735.) B. The best method for procuring the Metal is that of Allen and Aikin, subjecting tungstate of ammonia to an intense heat. The oxide is reducible by charcoal.

(736.) C. The Metal, from its extreme infusibility, has only been seen in a mass consisting of small agglutinated grains of a greyish-white colour, and some brilliancy. It is so hard as scarcely to be affected by the file. Its Specific Gravity, according to Bucholz, 17.4. It seems to assume a crystalline form on cooling, and not to be affected by the magnet.

(737.) D. Tungsten, if heated in an open vessel, will absorb oxygen, with which it may be made to combine in two proportions in forming brown and yellow oxides. Berzelius obtained the brown oxide, by passing a current of hydrogen over the yellow oxide in a glass tube heated to redness. Water was formed, and a brown oxide remained, which when heated in the open air burns like tinder, and becomes Tungstic Acid. See subsect. I.

(738.) E. F. G. Unexamined.

(739.) H. The sulphuret has been formed and examined by Berzelius.

(740.) I. The D'Elhuyarts formed alloys of Tungsten by subjecting a mixture of Tungstic Acid, charcoal, and any Metal, to a strong heat. In this manner it was combined with gold, silver, copper, iron, lead, tin, antimony, bismuth, and manganese. The principal obstacle to be overcome appeared to arise from the great infusibility of the Metal itself.

(741.) K. Tungstic Acid, as will be seen hereafter, forms Salts by uniting with bases; but Salts, in which any oxide of Tungsten performs the part of a base, have not been recognised.

(742.) L. An ore of Tungsten is recognised by calcining it with its own weight of nitre; a portion of the frit is soluble in water, forming a colourless solution. Nitric Acid throws down a white precipitate, which, by being well washed in boiling water, becomes yellow, and has the properties of Tungstic Acid.

(743.) M. None.

Subsect. 1—Tungstic Acid.

(744.) The Tungstic Acid of Scheele was in fact a triple Salt, but the true yellow oxide, which appears to possess acid properties, may be thus obtained. Let three parts of Hydrochloric Acid be boiled on one part of Wolfram. The clear Liquid is to be decanted off and left at rest. A yellow powder gradually separates, which is to be redissolved in ammonia; the clear solution, evaporated to dryness, leaves the yellow oxide in a state of purity. It is insoluble in water, and though it does not exert any action upon vegetable colours, it is capable of saturating bases. Good analyses have given such approximations to the theoretical numbers of the Table, that no others need here be given.

Tungstate of lime is found native. The tungstates of ammonia, potash, soda, and magnesia are soluble, those of lime, barytes, strontia, manganese, and iron are not so.

References to § 4.

Consult Scheele, *Ess.* vol. ii. p. 81; D'Elhuyarts, 5 A 2

Chemistry. *Mém. Acad. Thoulouse*, vol. ii.; Vauquelin and Hecht, *Jour. de Mines*, No. 19.; Klaproth on the Minerals of Cornwall; Aikin's *Dict.*; Berzelius, *An. Phil.* vol. iii.; Bucholz, *An. Phil.* vol. vi.; Bucholz, *Jour. de Ch.* vol. iii.; Berzelius, *Afhandlingar*, vol. iv.; Pelletier, *An. de Ch.* vol. xiii.

full action of this substance with tests, we must direct the reader to Dr. Thomson's *First Principles*. (a.)

Part II.

#### References to § 5.

(a) vol. ii. p. 77; consult also Hatchett, *Phil. Trans.* 1802, p. 49; Ekeberg, *Vetensk. Ac. Handl. Stockh.* 1802; Wollaston, *Phil. Trans.* 1809; Berzelius, *Afhandl.* vol. iv.; *Id. An. Phil.* vol. iv.; Wollaston, *Nich. Jour.* vol. xxv.; Berzelius, *An. de Ch. et de Ph.* vol. xxix. p. 303.

### Sect. V.—Columbium.

(745.) A. In the year 1801 Mr. Hatchett obtained from the analysis of a mineral in the British Museum, similar in appearance to chromate of iron, a new metallic oxide, possessed of acid properties. It had been sent from America, and, therefore, to the inferred metallic base of the oxide, he gave the name of Columbium. Ekeberg soon after discovered in a Swedish mineral a metallic oxide which he considered new, and called Tantalum, from the name of the mineral itself. Dr. Wollaston having examined the substance, found it identical with the Columbium of Hatchett. Columbium occurs in the mineral from Massachusetts, and in the tantalite and yttero-tantalite of Sweden.

(746.) B. Dr. Wollaston's method for obtaining this oxide from the mineral tantalite is as follows. Mix one part of tantalite with five of carbonate of potash and two of borax, and fuse in a platinum crucible. Soften the mass with water, and digest it in hydrochloric Acid. The iron and manganese are dissolved, and a white powder remains, which is the oxide of Columbium. By subjecting this oxide, mixed with charcoal, to an intense heat, Berzelius reduced it, although unable to produce a bead of fused Metal.

(747.) C. Columbium has a dark grey colour, is capable of metallic lustre, hard enough to scratch glass, and may be reduced to a dark-brown powder. Its Specific Gravity can scarcely be said to be accurately known.

(748.) D. When heated, Columbium takes fire, and burns feebly to an imperfect-grey oxide. It detonates slightly with nitre in a red-hot crucible. The white mass produced by this deflagration is a mixture of oxide of Columbium and potash. The potash may be separated by hydrochloric Acid, leaving behind a hydrous, white oxide, which has the singularity of being soluble in oxalic, tartaric, and citric Acids. After the water has been driven off by heat, this property disappears, and the pure oxide is insoluble in nitric and sulphuric Acids, but imperfectly so in the muriatic. It is capable of reddening vegetable blues, and with potash as a base it forms a crystallizable Salt. This is *Columbic Acid*, subsect. 1.

(749.) E. F. G. H. I. Little known, save that it has been alloyed with some other Metals.

(750.) K. Columbium resists the action of hydrochloric, nitric, and nitro-muriatic Acids.

(751.) L. Columbium must be tested in the state of columbic Acid, or a columbate. See, therefore, subsect. 1.

(752.) M. None.

#### Subsect. 1.—Columbic Acid.

(753.) On this point we may briefly state that Columbic Acid is scarcely at all soluble in water. Insoluble in Acids, save the fluoric. Soluble in acid tartrate of potassa; also in potassa and soda. For the

### Sect. VI.—Antimony.

(754.) A. The Ancients obtained with their silver ores an oxide of this Metal, to which the name *στίβιον*, or *stibium*, was applied. Pliny thus speaks of it. *In iisdem argenti metallis invenitur, ut propriè dicamus, spumæ lapis candidæ nitentisq; non tamen translucentis, stibium appellant, alii stibium, alii alabastrum, alii lurbason.* Lib. xxxiii. ch. vi. He enumerates its medicinal virtues, and particularizes its application to the eyes. Thus employed as an ornamental pigment, its use is of high antiquity; at least that such a custom prevailed we learn from *Izekiel*, ch. xliii. v. 40., and among the Eastern ladies it is continued to this day. They colour the eyelids black with a substance of which the Arabic name is *Kohl*, thus being some preparation of Antimony. Dr. Thomson has shown, by a singular quotation from Thallinus, that its use was continued in Spain during the Middle Ages, under the name of "*pie dra de alcohol*." The Alchemists were well acquainted with the substance, and doubtless received from Arabia or Egypt the name *kohl*, with the article *al* prefixed; hence their usual term *alcohol*, though many other names were given to it from its properties. In 1624, the *Currus Triumphalis Antimonii* of Basil Valentine, a Monk of Erfurt, appeared. As the title implies, the virtues of this mineral form the subject of the Work. It is not improbable that through him, or some one in his time, the word Antimony came into use. Legends tell that the Monkish experimentalist, who practised as a Physician, made trial of its virtues upon the hogs of the Convent. The medicine acted as a brisk cathartic, and the pigs speedily fattened. Encouraged by this happy result, he administered it to some of his brother Monks; but the dose being too violent it proved fatal, and hence the name *ἀντι μωχαίος*, or "*Anti-moine*."

It is found but sparingly in the state of an oxide, but very abundantly as a sulphuret, which ore is the *crude Antimony* of Commerce; also in native crystals of considerable purity.

(755.) B. Antimony may be obtained from its sulphuret for the purposes of the laboratory by mixing three parts of the ore with two of tartar and one of nitre; this powder is to be gradually projected into a hot crucible, which is then exposed for three-quarters of an hour to a furnace or forge-heat. On cooling, the button of Antimony is found at the bottom of the crucible. By this process the Metal is not obtained in a state of great purity; for delicate purposes it must be revived from the oxide. Thenard suggests the passing a current of hydrogen over the oxide in a heated porcelain tube, as the most unobjectionable method.

(756.) C. In colour, Antimony is greyish-white, with considerable brilliancy. Its texture is laminated and

**Chemistry.** imperfectly crystalline. According to Haüy, (a.) the primary form is an octohedron. By friction it communicates to the fingers a peculiar taste and smell. Its hardness nearly equals gold. Its Specific Gravity, according to Hatchett, is 6.71. It is so brittle as to be easily pulverized. According to Muschenbroeck, a wire one-tenth in diameter supports a weight of about ten pounds. It fuses at about  $810^{\circ}$  of Fahrenheit, and is volatilized by greatly increased heat; but from the experiments of Thenard it would appear that the Metal is fixed if air be excluded, and that the volatilization which takes place is that of the oxide.

(757.) D. There is considerable difference of opinion as to the number of oxides which Antimony is capable of forming, but of three at least there is good evidence. By exposure to air or water, the Metal undergoes no alteration, but at a red heat it decomposes steam with such rapidity as to produce a violent explosion.

1. The protoxide is a white or grey powder, easily fusible. It may be obtained by dissolving the Metal in hydrochloric Acid, and diluting the solution largely with water; a white precipitate is obtained; which, after being well washed, is to be boiled in a solution of carbonate of potassa, to remove an adhering portion of hydrochloric Acid. This powder, when again washed and dried, is the protoxide.

2. The hemidentoxide (deutoxide of some) is a fine white powder, not so fusible as the former, nor so easily soluble in Acids, and insoluble in water; it is obtained by heating the protoxide in an open vessel nearly to redness. It takes fire, absorbs oxygen, and is converted into the oxide. It is produced also by the action of hot nitric Acid upon Antimony. By heating the Metal in a furnace with free access of air, a white oxide is sublimed, (argentine flowers of Antimony,) which Thomson considers to be this, while Thenard asserts that it is the former oxide.

This oxide possesses acid properties, and combines with bases producing the *Antimonites*. It has been called Antimonious Acid. See subsect. 1.

3. The remaining known oxide, the deutoxide, (peroxide of some,) is also an Acid, and called the Antimonic. See subsect. 2. It may be formed by mixing six parts of nitre and one of Antimony in a silver crucible, and exposing it to a low red heat for an hour. The excess of alkali is to be washed off with a little cold water. Digest the remaining powder in hot water, which will dissolve a part. From this solution, acetic Acid precipitates a hydrate of antimonic Acid. The water may be driven off by a gentle heat, and the powder thus obtained is incapable of combining with Acids, but reddens vegetable blues; and is, in fact, completely an Acid, as it unites with bases to form Salts. By a red heat it is converted into the preceding oxide.

Of the constitution of these oxides no very decided account can be given, the reader is therefore referred to the Table for the nearest theoretical assumption.

The antimoniate of potash is formed in the above process, and many metallic antimoniates exist, but have not yet been made the subject of investigation.

(758.) E. The action of chlorine upon this Metal produces the following beautiful experiment. Into a stopped glass jar containing chlorine, pour, by means of a funnel, some finely powdered Antimony, which has been previously warmed. The rapid combination produces a beautiful shower of fire within the jar.

(759.) F. Unexamined.

(760.) G. Iodine combines with Antimony, but by water is again separated into hydriodic Acid, and the white oxide. Part II.

(761.) H. With carbon, boron, silicon, azote, and hydrogen, we know of no compound, but with phosphorus, sulphur, and selenium, it readily unites.

(762.) I. With the Metals it readily unites, and generally to the destruction of their ductility.

(763.) K. Boiling sulphuric Acid undergoes a violent action upon Antimony; it is decomposed, giving out sulphurous Acid Gas; an imperfect sulphate is produced, which, however, is decomposed by a plentiful effusion of water, and the white oxide of the Metal subsides to the bottom.

The sulphurous Acid has no action upon Antimony, but it decomposes many of its Salts. From the hydrochlorate, a white precipitate is produced, which, according to Aikin, is a true sulphate of Antimony.

Upon this Metal, nitric Acid, even when cold, undergoes rapid decomposition; nitrous Gas is evolved, and a white oxide is produced. If the Antimony be reduced to fine powder, and mingled with just Acid enough to form a paste, the action is so violent as to cause inflammation. Another singular consequence of the partial decomposition of the water, together with that of the Acid, is that the liberated hydrogen of the former unites with the azote of the latter, and ammonia is produced. The addition of a small quantity of fixed alkali or caustic lime will disengage the Ammonia, which may be recognised by its pungency, or by the fumes of hydrochloric Acid.

The hydrochloric Acid dissolves Antimony, but in very small quantity; on the oxide its action is much greater; a thick, honey-like substance is the result, which formerly went by the name of *Butter of Antimony*, and is a highly corrosive substance.

Strong nitromuriatic Acid dissolves this Metal in considerable quantity, but the whole is again precipitated in the state of an oxide by water.

From all these instances we may fairly conclude that Antimony, when oxidated in the higher degrees, can no longer as a base unite with Acids to form Salts; but it may assist in the formation of Salts with certain bases, to which it performs the part of an Acid.

The only true Salts of Antimony then contain the protoxide; of the mineral Acids there probably are few if any, as their own decomposition furnishes oxygen for the formation of the insoluble white oxide. From the vegetable Acids, the acetate, succinate, benzoate, oxalate, and tartrate have been described. One triple Salt, however, claims peculiar notice, as the *Tartar Emetic* of Medical writers. It consists of tartaric Acid, potash, and protoxide of Antimony. Alkalis, alkaline earths, sulphurets, several metals, and astringent vegetable decoctions, decompose it. With any of these, therefore, it ought never to be conjoined in a prescription.

The solutions of the Salts of this Metal are generally yellow, and precipitable by water. Prussiate of potassa and tincture of galls give a white precipitate, but only from their water determining the deposition of the white oxide. From hydrosulphurets, a yellow precipitate is produced. A plate of iron or zinc throws down the Metal in the state of a black powder, especially if the solution be acidulated.

(764.) L. In the Arts an alloy of this Metal with lead is used for the plates upon which music is

**Chemistry.** engraved; and with tin it forms one kind of pewter. It enters also with lead and copper into the composition of printers' types. Its oxide assists in the vitrification of earthenware, and gives to glass an amethystine hue. Combined with oxide of lead, it forms a paint called *Nipples yellow*, and enters into some enamels. Of its application to medicinal purposes the tartrate has been noticed. The *Glass of Antimony* of the old Pharmacopœia is a fused sulphuret. The *Kermes Mineral* is an hydrosulphuretted oxide. The celebrated Fever-powder of Dr. James appears, from the analysis of Dr. Pearson, (b) to be a combination of phosphate of lime with oxide of Antimony, which is imitated in the *Pulv. Antimonialis* of the *Materia Medica*.

#### Subsect. 1.—Antimonious Acid.

(765.) If Antimony be burned or strongly heated in an open vessel, an oxide is formed, the constitution of which is at once expressed by our term of the hemideutoxide; it is condensed upon any cold surface in the form of shining, white, acicular crystals. This substance was formerly called *Argentine flowers of Antimony*. It unites with alkalis to form a class of Salts.

#### Subsect. 2.—Antimonic Acid.

(766.) Dr. Thomson obtained this Acid by dissolving pure metallic antimony with nitric Acid in a platinum crucible. The solution was evaporated to dryness, and exposed for some hours to a heat of 500° Fahrenheit. This acid oxide is a yellow powder, and is converted by a red heat into the oxide preceding. The same able Chemist has suggested, and with great probability, that the hemideutoxide is a compound of one atom of the protoxide + one atom of the deutoxide. Berzelius formed and described the Antimoniate of potassa.

#### References to § 6.

(a.) *Jour. de Mines*, An. 5. (b.) *Phil. Trans.* 1791; consult also Basil Valentine, *Currus Triumphalis Antimonii*; Meuseri *Analysis Antimonii Physico-Chemicus rationalis*, 1788; Lavoisier and Laplace, *Mém. Par. Acad.* 1781; Thenard, *An. de Ch.* vol. xxxii.; Proust, *Jour. de Phys.* vol. iv.; Berzelius, *Nich Jour.* vol. xxiv. xxv.; *An. Phil.* vol. i.; Thomson, *An. Phil.* vol. iv.; J. Davy, *Phil. Trans.* 1812; Bergman, *Opusc.* vol. iii.; Thomson, *First Principles*, vol. ii. p. 40.

### SECT. VII.—Uranium.

(767.) A. On examining a Saxon mineral called *Pechblende*, Klaproth, in 1789, discovered that it was the sulphuret of a new Metal. Herschel had just discovered his new Planet, and as the German Astronomers gave to it the name of Uranus, the Chemist gave to his new Metal the name of Uranium. The beautiful green uranite of Cornwall is an hydrated oxide of this Metal.

(768.) B. To obtain the Metal from pechblende by digestion in nitric Acid, the Uranium, iron, copper, and lime are taken up. Evaporate to dryness, and redissolve in water, which will leave the peroxide of iron. By digestion in ammonia the Uranium is precipitated, and the copper retained in solution. The precipitate is to be again dissolved in nitric Acid, evaporated and crystallized. The green crystals are

picked out, slightly washed, dissolved in water, and, by a second crystallization, they are supposed to be obtained free from the lime. By exposure to a red heat a yellow, pulverulent oxide remains. This oxide, mixed with one-twentieth of charcoal powder, and exposed to intense heat, is reduced. In this, and probably in many other cases, too much charcoal should not be employed.

(769.) C. Thus obtained, Uranium is not a very compact button, as a much greater heat is required for its perfect fusion than our furnaces can produce. Its physical properties are little known; it yields to the file, and, according to Professor Clarke, of Cambridge, a pure bead, produced by acting upon the nitric green oxide with the Gas blowpipe, was brittle.

(770.) D. At a red heat, in an open vessel, Uranium is converted into a greyish-black powder, which, by continued heat, is unaltered, and is the protoxide. The yellow powder, above described, is the deutoxide, which is also obtained by precipitation from the nitrate by an alkali.

It would appear from recent experiments, especially those of Dr. Thomson (a.) and Arfwedson, (b.) that the higher oxide of Uranium is, in fact, possessed of acid properties, and can neutralize bases. The constitution of the oxides of Uranium is by no means well settled; for, supposing the dark-green oxide to be a protoxide, it remains doubtful whether the yellow oxide is a hemideutoxide, or a deutoxide: Thomson is of the latter opinion.

(771.) E. F. G. Little studied, or unknown.

(772.) H. Bucholz succeeded in forming an artificial sulphuret of Uranium.

(773.) I. Nitric Acid readily dissolves Uranium, or its oxide; and by evaporation, a crystallized nitrate, of a lemon-yellow colour, is obtained. It is deliquescent, very soluble in water, and moderately so in ether, but shortly undergoes decomposition. A sub-nitrate, insoluble in water, is described by Bucholz. Sulphuric Acid has very little action on Uranium. But it dissolves, with some difficulty, the oxide, if assisted by heat, and a crystallized sulphate may be obtained. Berzelius describes a seleniate and biseleniate. The phosphate, arseniate, tungstate, molybdate, and tartrate may be found by precipitation from a Salt of Uranium with Salts of these Acids. Richter obtained also the borate, oxalate, citrate, melleate, benzoate, and succinate. Acetic Acid dissolves the oxide, and forms a crystallizable salt soluble in water.

Besides these Salts, in which oxides of Uranium constitute the base, it is quite well established that the yellow oxide of Uranium performs the part of an Acid also to certain bases. See subsect. 1.

(774.) K. For the reagent effects of Uranium, consult a valuable series of facts given in Thomson's *First Principles*, vol. ii. Generally speaking, the caustic alkalis give yellow precipitates with Salts of Uranium not soluble in excess of alkali; with their carbonates a white one, which is soluble in excess. Prussiate of potassa a dark, red-brown precipitate.

(775.) L. With proper fluxes the oxide of Uranium gives an orange colour to porcelain.

#### Subsect. 1.—Uranic Acid.

(776.) To preserve the uniformity of our plan we introduce this name. Uranate of barytes is described

Chemistry. by Berzelius. This Acid seems to have a great tendency to take part in the formation of double Salts.

References to § 7.

(a.) *First Principles*, vol. ii. p. 2. (b.) *An. Phil. N. S.* vol. vii. See also Klaproth, *Crell's Annals*, vol. i.; Bucholz, *Gehlen's Jour.* vol. iv.; Klaproth, *Analyt. Essays*, Eng. Trans. vol. iv.

Sect. VIII.—Cerium.

(777.) A. In the year 1750, a mineral, having considerable resemblance to tungsten, was found in the copper-mine of Bastnäs in Sweden. Bergman published an attempt at its analysis by MM. D'Elhuyart, by which it was proved not to be tungsten. Klaproth afterwards declared it to contain a new earth, which he called *Ochroita*. Hisinger and Berzelius made a more complete examination of the substance, and, considering it a metallic oxide, they gave to the Metal the name of Cerium, from the coincidence of the discovery of the Planet Ceres about the same time. It has subsequently engaged the attention of Vauquelin, Thomson, and Laugier. Three minerals contain this substance, two from Sweden, and one from Greenland.

(778.) B. Cerium is best obtained by the process of Laugier. The mineral Cerite is dissolved in nitro-muriatic Acid; a precipitate is produced by ammonia, which is well washed, and, while still moist, is treated with a solution of oxalic Acid, which dissolves out the oxide of iron which had been thrown down; the remaining powder is, after calcination at a red heat, pure oxide of Cerium. Several attempts have been made to reduce this oxide to the metallic state, but with partial success; for though a metallic powder has been produced, it has never been formed into a mass, so that its physical properties are almost unknown. Sir H. Davy effected the decomposition of the oxide of Cerium by the action of potassium.

(779.) C. M. Vauquelin obtained some small grains of metallic Cerium, which were brittle and of a white colour. According to Messrs. Children and Thomson, Cerium may be volatilized by a very intense heat.

(780.) D. If Cerium be dissolved in nitro-muriatic Acid; the solution neutralized with caustic potassa; then precipitated by tartrate of potassa; and lastly, after washing, be calcined, oxide of Cerium is obtained. This is Cerium, in its highest degree of oxygenation. The two oxides of this Metal would seem to be a protoxide and a hemideutoxide.

(781.) E. F. G. Unknown.

(782.) H. Laugier obtained a carburet of Cerium; and there is reason to suppose that a phosphuret may be formed. Also a sulphuret by indirect processes.

(783.) I. According to Gahn, Cerium would not unite with lead; but Vauquelin succeeded in forming an alloy with iron.

(784.) K. According to Vauquelin, the reduced metallic powder is insoluble in all unmixt Acids, and not easily so in even the nitro-muriatic. The oxides are soluble in most Acids. The Salts of the protoxide at present known are the protonitrate, protosulphate, protocarbonate, protoseleniate, and protoxalate. Those of the red oxide are, the nitrate, sulphate, seleniate, and oxalate. There also exist combinations of oxide

of Cerium with the phosphoric, arsenic, molybdic, acetic, benzoic, succinic, tartaric, and citric Acids; but of the state of oxidation of the Metal in these cases we are not well assured; for the most part they seem to contain the protoxide. A double Salt of sulphuric Acid with potassa and oxide of Cerium, is described by the Swedish Chemists.

(785.) L. Of the protoxide, the Salts are colourless, or white; and of the peroxide they are yellow. Their solutions in water have a sweet taste. Gallic Acid and hydrosulphuric Acid Gas give no precipitate. Hydrosulphuret of potash and prussiate of potassa give a white precipitate. Oxalate of ammonia produces a white precipitate soluble in nitric and hydrochloric Acids. Tartrate of potash gives no precipitate, but arseniate of potash gives a white precipitate. Succinate of ammonia does not precipitate Cerium from the acetate, which furnishes a ready means of separating iron from Cerium.

(786.) M. None known.

References to § 8.

(a.) Bergman, *Opusc.* vol. vi.; Klaproth, *Gehl. Jour.* vol. ii., or *Nich. Jour.* vol. viii.; Hisinger and Berzelius, *Nich. Jour.* vol. ix.; Gahn, *Gehl. Jour.* vol. iii.; Vauquelin, *An. de Ch.* vol. i. and vol. liv; Thomson, *Phil. Trans. Edin.* vol. vi.; Laugier, *An. de Ch.* vol. lxxxix.; Hisinger, *An. Phil.* vol. iv.

Sect. IX.—Cobalt.

(787.) A. Cobalt was recognised as a distinct metallic substance by Brandt in 1733, but had long been used to give a blue colour to glass. According to Lehman, Christopher Schurer, a glass maker at Platten, was the first to use it thus in about 1540. Cobalt is found in several states of mineral combination, and is almost constantly attended by arsenic.

(788.) B. For commercial purposes, the Cobalt ore is roasted; by which volatile and fusible substances are removed, and some silica within an impure oxide remains, which is called *zaffre*. Many processes have been recommended for obtaining pure Cobalt; one of the best is as follows. Reduce *zaffre* to the metallic state, by mixing it with thrice its weight of black flux, a little oil, and a little salt; expose this mixture to a strong heat in a crucible for some hours, and a button of Cobalt will be found at the bottom of the crucible. In this state it is usually alloyed with iron, copper, nickel, and arsenic. Pulverize the metallic button, and calcine with four parts of nitre; after which hot water will remove the arseniate of potassa. Dissolve the residuum in dilute nitric Acid, and precipitate the copper by a plate of iron. By filtering, evaporation to dryness, and digestion in hydrate of ammonia, the oxides of nickel and Cobalt will alone be taken up. Expel the excess of ammonia by heat, and add dilute hydrate of potassa, which will precipitate the nickel. By immediately filtering and boiling the clear liquor the oxide of Cobalt is precipitated, and may be reduced by subjecting it to a strong heat with charcoal and a little oil.

(789.) C. Thus obtained, Cobalt is of a reddish-grey colour, of a fibrous or laminated texture. Brittle, but said to be malleable when heated. Its Specific Gravity has been stated at from 7.7 to 8.7. It is not

**Chemistry** volatile; and, after fusion, may, by care, be obtained in a crystalline form. Like iron and nickel, it possesses permanent Magnetic properties.

(790.) D. Cobalt at a red heat in an open vessel undergoes oxidation. The protoxide is however best obtained by dissolving the Metal in nitric Acid, and precipitating by hydrate of potassa: the precipitate is at first blue, but becomes black, and is the higher oxide of this Metal. By exposing this oxide to a low red heat, one portion of oxygen is driven off, and protoxide, which has a beautiful blue colour, is produced.

(791.) E. The chloride may be formed by gently heating filings of the Metal in chlorine; it is also formed, by evaporation of the hydrochlorate, and is a very definite compound.

(792.) F. G. The iodide and fluoride are unknown.

(793.) H. The phosphuret, sulphuret, and selenuret, have been examined, but of any combination with carbon, boron, silicon, hydrogen, or nitrogen, we are ignorant.

(794.) I. Cobalt has been alloyed with gold, platinum, tin, copper, iron, antimony, arsenic, and lead; but it would scarcely, if at all, unite with silver, mercury, bismuth, or zinc.

(795.) K. As we have before seen, Cobalt is soluble in nitric Acid when heated, and red prismatic crystals may be obtained.

The muriatic Acid attacks this Metal but with great difficulty, and the solution was formerly known by the name of Hellot's Sympathetic Ink; a better Salt for this purpose will, however, be described hereafter. The oxide is readily soluble.

At a boiling heat, sulphuric Acid is decomposed upon Cobalt, and a soluble sulphate remains, but the oxide is not very soluble in this Acid. Carbonate, borate, seleniate, arseniate, antimoniate, antimonite, oxalate, and tartrate of Cobalt, may be formed by precipitation where the Salts are neutral. Oxalic Acid attacks and dissolves metallic Cobalt, but phosphoric, fluoric, tartaric, and acetic Acids, only dissolve the oxide. The *Acetate of Cobalt* forms an excellent sympathetic ink, by which if any thing be written or painted upon paper, it is invisible when cold, but becomes of a fine azure blue when exposed to heat. The most probable cause that has been assigned for this change is, that, when suffered to cool, the muriate or acetate of Cobalt, being very deliquescent, absorbs moisture, and undergoes a sufficient dilution to be colourless; but that by heating they become concentrated, and the green or blue colour is developed. This view of the matter is confirmed by the fact, that the same colour is produced by exposing the washed paper to the absorbent action of quick-lime, or sulphuric Acid in an exhausted receiver.

Neutral solutions of the Salts of Cobalt are generally of a reddish colour.

(796.) L. In neutral solutions of Cobalt the alkalis produce a blue precipitate, prussiate of potassa a light-green one. Hydrosulphuric Acid Gas no precipitate; but hydrosulphuret of potash a black one, soluble in excess of the precipitate. Gallic Acid produces no change, but tincture of galls gives a white precipitate. Metallic zinc produces no precipitate, neither does its hydriodate, nor that of potassa.

(797.) M. Cobalt is employed in the Arts to give a blue colour to glass, enamel, and porcelain. *Zaffre* has been already described, but as it is found in Com-

merce it is always mixed with two parts of powdered flint.

*Smalt* is a finely pulverized glass, coloured by oxide of Cobalt. Aikin states that so high is the colouring power of this metallic oxide, that one grain will give a full blue colour to 240 grains of glass.

#### References to § 9.

Brandt, *Acta. Upsal.* 1733 and 1742; Lehman, *Cadmialogia*; Bergman, *Opusc.* vol. ii.; Tassaert, *Ann. de Ch.* vol. xxviii.; Fourcroy, *Jour. de Mines, Disc. Prélim.*; Thenard, *Ann. de Ch.* vol. xlii.; Proust, *Ann. de Ch.* vol. lx.; Richter, Gehlen's *Jour.* vol. ii.; Bucholz, Gehlen's *Jour.* vol. iii.; Phillips, *Phil. Mag.* vol. xvi.; Rothoff, *Ann. Phil.* vol. iii.; Thenard, *Jour. de Mines*, vol. xii. p. 215.

#### Sect. X.—Titanium.

(798.) A. In the year 1791, the Rev Mr. Gregor published the analysis of a black sand found in the parish of Menachan in Cornwall. Finding that it contained the oxide of a new Metal, it received the name of Menachine from Kirwan. Little interest was excited till, four years afterwards, Klaproth discovered that what was called red schorl consisted of the same oxide nearly in a state of purity. To the Metal he gave the name Titanium, which is generally adopted. It has since been found in anatase, iserine, and sphene, and frequently forms those beautiful brown filaments which traverse rock crystal.

(799.) B. The native red oxide is not soluble in Acids, but may be decomposed by fusion with two parts of potash, or six parts of its carbonate. The fused mass is to be digested in diluted hydrochloric Acid, which is to be decanted off when it has removed all the soluble part. To this hydrochloric solution, oxalate of ammonia is to be added; by which, oxalate of Titanium is precipitated, while the iron remains in solution. By calcination, the vegetable Acid is destroyed, and a yellow oxide remains, which becomes white on cooling. The reduction of this oxide has proved of the utmost difficulty, and has been frequently attempted without success. By forming the oxide into a paste with oil, and exposing it to a most intense heat, Laugier appears to have effected it.

(800.) C. The colour of the "Metal" produced was that of gold; it was brittle, but in a slight degree elastic, having considerable lustre, but highly infusible; according to Vauquelin it may be volatilized by an intense heat.

(801.) D. When heated with access of air, it changes its colour and undergoes oxidation, forming a blue powder, which is said to be the first oxide. The native red schorl is the second, and the last is the white powder already described.

This powder has feeble acid properties; hence it has been called Titanic Acid. (Subsect. 1.)

(802.) E. Metallic Titanium unites with chlorine; and it would appear that two chlorides of Titanium exist. (a.)

(803.) F. G. Unknown.

(804.) H. Sulphur was united with Titanium by Rose, and with phosphorus by Chenevix.

(805.) I. Vauquelin and Hecht were unable to alloy Titanium with silver, copper, lead, or arsenic; but

**Chemistry** they did combine it with iron. Dr. Wollaston obtained similar results.

(806.) K. Though nitric Acid has little action on either the Metal or the red oxide, it will, if aided by heat, dissolve the carbonate, and a crystallized nitrate may be obtained, provided that the Metal be in its first degree of oxidation. The Metal is soluble (though the red oxide is not) in hydrochloric Acid, and a Salt forming cubic crystals is produced; but according to Vauquelin a gelatinous mass is produced by evaporation, which by increased heat is decomposed, chlorine is liberated, and an oxide precipitates, which is insoluble in hydrochloric Acid, but yields to the nitric. Hence it is inferred that the hydrochlorate contains the white oxide and that no combination can exist between this Acid and the protoxide. Boiling sulphuric Acid oxidates and dissolves the Metal, but affects not the red oxide; it acts readily on the carbonate, but this metallic sulphate has not as yet been seen in a crystalline form. The phosphoric and arsenic Acids, if added to the solutions of this Metal, produce insoluble white precipitates. The carbonate is formed by fusing together six parts of carbonate of potassa and one part of the red oxide; the mass is to be well washed with water, and the insoluble white powder remaining is the Salt. Oxalic and tartaric Acids produce also white precipitates, but these are again redissolved by any excess of Acid.

The Salts are colourless, and have different degrees of solubility.

(807.) L. Alkaline carbonates produce a white flaky precipitate, prussiate of potash a grass-green inclining to brown; "but if an alkali is added after the prussiate, the precipitate becomes purple, then blue, and at last white." Hydrosulphuret of potash produces a dirty-green precipitate; sulphuretted hydrogen produces none at all; infusion of galls a bulky reddish-brown precipitate. A rod of tin immersed in a clear solution of Titanium becomes gradually surrounded by a fine red cloud, and a rod of zinc by a blue one.

(808.) M. In the Arts, Titanium has been sparingly employed to produce a brown or yellow colour on porcelain.

#### Subsect. 1.—Titanic Acid.

(809.) The existence of this Acid is doubtful, for Rose has stated that he could not detect true acid properties in the oxide of Titanium; we leave it, however, for future examination.

#### References to § 10.

(a.) Gregor. *An. Phil. N. S.* vol. ix. p. 18. (b.) Rose, *An. Phil. N. S.* vol. vi. p. 369; Gregor. *Jour. de Ph.* vol. xxxix; Klaproth, *Beitr.* vol. i. p. 233, and vol. ii. p. 226; Vauquelin and Hecht, *Jour. de Mines*, No. 15; Crell, *Annals*, 1799, vol. i. p. 183; Chenevix, *Nich. Jour.* vol. v. p. 134; Lampadius, *Nich. Jour.* vol. vi. p. 63; Laugier, *An. de Ch.* vol. lxxxix.

#### Sect. XI.—Bismuth.

(810.) A. Bismuth was unknown to the Ancients, but appears to have been early recognised by the German miners. According to their speculations it was an imperfect silver, but by the successive researches of Chemists it was first deemed an alloy, and at length recognised as a peculiar Metal. It is found native, but contaminated with arsenic, as an oxide, and as a sulphuret.

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(811.) B. Being easily fusible, it is separated from its ores by subjecting them to the heat of a furnace in iron tubes, inclined so that the Metal may run out at one end.

(812.) C. In colour, Bismuth is reddish-white, and has a laminary structure. In hardness it is inferior to copper. According to Hatchett its Specific Gravity is 9.822. It is not malleable, nor of great tenacity. Its fusing point is 451° according to Berzelius, but Gay Lussac makes it as high as 541. If a mass of Bismuth, fused in a crucible or ladle, be suffered partly to congeal, and the fluid portion be poured off from the other, a very beautiful crystallization is seen in rectangular parallelepipeds. The primary form, according to Haüy, is an octahedron. (*Jour. de Mines*, An. 5.) It has long been said that, by increased heat, Bismuth may be sublimed; this, however, is denied by Thenard.

(813.) D. The action of air or water is not alone sufficient to produce oxidation, but by continuing the Metal in a state of fusion with free access of air, a film of oxide forms upon the surface. At a strong red heat it takes fire, emitting a yellow smoke, which when condensed is no longer volatile, and forms the yellow oxide of Bismuth. It is tasteless, and insoluble in water, but fusible.

(814.) E. If Bismuth, finely powdered, be introduced into chlorine it takes fire, and the metallic chloride is produced.

(815.) F. Unknown.

(816.) G. Iodine, by the aid of heat, enters into combination with Bismuth, and this iodide, though insoluble in water, may be dissolved in caustic potassa without precipitation.

(817.) H. Bismuth combines readily with sulphur and selenion, scarcely, if at all, with phosphorus, and not with hydrogen or carbon.

(818.) I. All Metals seem capable of uniting with this to form alloys, and in general a great increase of fusibility is the result. Newton's fusible Metal is a striking example, consisting of eight parts of Bismuth, five of tin, and three of lead. It melts at a heat considerably below that of boiling water, and the addition of one part of mercury adds still more to its fusibility.

(819.) K. The action of nitric Acid upon Bismuth is very violent, much nitrous Gas is evolved, and the Metal undergoes oxidation. With slightly dilute Acid a soluble nitrate is produced, which on cooling is precipitated in small crystals.

Cold sulphuric Acid exerts no action upon Bismuth, but by the assistance of heat, the Metal is converted into a white powder, and sulphurous Acid is evolved. By washing with a small quantity of water, a portion of the metallic sulphate is carried off, and may be obtained by evaporation.

Arsenic Acid digested upon this Metal with a moderate heat, converts it into a white powder, which is arseniate of Bismuth.

Hydrochloric Acid, if heated, acts upon Bismuth, and very readily on its oxide, and a crystallizable hydrochlorate is produced, which is, like the nitrate, precipitable by water; by the action of heat the muriate becomes a chloride, which, according to Dr. J. Duvy, is not volatile.

The following Acids, though producing little or no effect upon this Metal, combine with its oxide, and produce Salts; viz. the carbonic, boracic, phosphoric, sulphurous, molybdic, oxalic, acetic, and tartaric, which



**Chemistry.** are all scarcely, if at all, soluble in water. The benzoic and succinic form soluble Salts. There is, according to Morveau, this singularity on the part of acetic Acid, that its presence prevents the precipitation of Bismuth from its nitric solution by water. The formation of the above mentioned Salts is best effected by adding a solution of the Salt of potash with the given Acid to the nitric solution of the Metal.

(820.) L. In all the acid solutions of Bismuth, (acetic?) the addition of water produces a white precipitate, consisting of the metallic oxide generally united to a small portion of Acid; thus the white powder falling from the nitrate is an oxide containing a little nitric Acid. Prussiate of potash gives a white precipitate, and infusion of galls a yellowish one. By hydriodic Acid a chocolate precipitate, sulphuretted hydrogen a dark brown. By a plate of copper or tin a precipitate of the pure Metal is produced.

(821.) M. In the Arts, Bismuth enters in the composition of soft solders. An alloy of two bismuth, one lead, one tin, and four mercury, is used for silvering the inside of glass globes. The interior of the globe is well dried, and a small quantity of the alloy introduced; by immersion in hot water it melts, and by turning the globe about, a sufficient coating adheres to its inner surface. The flake white of painters is the precipitate from the nitrate by water, formerly called *Magistery of Bismuth*, and the pearl-white is said to be a similar precipitate from the hydrochlorate or tartrate. It is proposed to use it instead of lead in assaying.

#### References to § 11.

Pott, *Exercitationes Chem.* Berl. 1738; Wenzel, *Verwandschaft*; Berzelius, *An. de Ch.* vol. lxxxvii; Lagerhjelm, *An. Phil.* vol. iv.; Chaudet, *An. de Ch. et de Ph.* vol. viii.

### Sect. XII.—Copper.

(822.) A. This Metal, occurring frequently in the native state, was one of the earliest known to the Ancients: alloyed with tin it formed the bronze of which ancient weapons were made before iron was obtained in sufficient quantity to be applied to this purpose. The armour of the warriors at the siege of Troy was of bronze, and the knives of the ancient Egyptians were found by Dr. E. D. Clarke to consist of the same alloy.

Copper is found in a state of native purity, as an oxide and sulphurets, and also as a Salt, carbonate, hydrochlorate, phosphate, sulphate, and combined with many other substances.

(823.) B. Various processes are employed for extracting this Metal from its ores. The sulphurets are roasted in reverberatory furnaces, once, or oftener, as the case may require; and, finally, reduced by heating them in an appropriate furnace with small-coal. To render it sufficiently pure for sale, it is remelted, and granulated by falling into cold water several times over; and lastly, refined by again fusing it with charcoal powder. Pure Copper for Chemical purposes is best obtained by placing a plate of iron in a slightly acid solution of Copper; the Metal is deposited in the form of a fine, brown powder, which is to be washed with a little dilute sulphuric Acid, to remove any adhering iron.

(824.) C. Copper has great brilliancy, and a fine red colour. It acts disagreeably on the organs both of smell

and taste. Specific Gravity 8.60—8.69, Hatchett. It is harder than silver; has such malleability as to be beaten out into extremely thin leaves. Its tenacity is very great, according to Mr. Rennie: (*Phil. Trans.* 1818:) a wire of cast Copper, one-tenth of an inch in diameter, is broken by a weight of 190.7 pounds, and one of the same size of hammered Copper would be broken by a weight of 337.9 pounds: these results are calculated from experiments on longer bars. (Thomson.) Copper is calculated to melt at 1450° Fahrenheit, and is volatilized by increased heat. By slowly cooling it, Mongez obtained crystals in the form of quadrangular pyramids.

(825.) D. This Metal does not decompose water at ordinary temperatures, or its vapour at a red heat, but by long exposure to air and moisture a mixture of carbonate and oxide is formed upon its surface, (verdigrise.) By heating a plate of Copper to redness in atmospheric air, a red oxide is formed at the surface, and may be detached in laminae. Two oxides of Copper are well known to Chemists, and a third is admitted by Thenard.

To obtain the lowest oxide, dissolve the Metal in hydrochloric Acid by the assistance of heat. Let this green solution be put into a phial with some metallic Copper, and cork it closely. The Liquid gradually acquires a brown colour, and deposits crystals like grains of sand. By adding hydrate of potassa to a solution of these in water, the orange-coloured oxide is precipitated. (Chenevix, *Phil. Trans.* 1806; Berzelius, *An. de Ch.* vol. lxxviii)

The scales above described as forming upon the surface of heated Copper, are composed of the higher oxide, but retain some particles of Metal. By exposure to heat the whole becomes a uniform black powder. The same substance is obtained by precipitating a solution of Copper in nitric Acid, with a caustic, fixed alkali: and exposing the precipitate to a red heat to drive off the water.

The black oxide last described is chiefly found in the Salts of Copper, and was heretofore considered the highest oxide; but Thenard obtained, by means of an oxygenated Acid, a still higher oxide of this Metal. (a.)

If with Thomson, Prout, and Wollaston we consider the atom of Copper = 32, the constitution of these oxides will be,

Oxygen.	Copper.
The red oxide = 8 or one atom	+ 64 or two atoms,
The black oxide = 8 or one atom	+ 32 or one atom,

forming a suboxide, and an oxide.

But if with Thenard we call the atom of Copper = 64,

Oxygen.	Copper.
The red oxide = 8 or one atom	+ 64 or one atom,
The black oxide = 16 or two atoms	+ 64 or one atom,

forming a protoxide and a deutoxide.

Thenard could not fix the constitution of his higher oxide.

(826.) E. Chlorine readily combines with Copper-filings, forming a volatile chloride and a fixed subchloride of the Metal. These two compounds may also be obtained by evaporating the sub-hydrochlorate and the hydrochlorate of the Metal respectively.

(827.) F. Unexamined.

(828.) G. The iodide of Copper is a brown, insoluble powder, formed by adding hydriodic Acid to solutions of the Metal, or by heating Copper in contact with iodine.

(829.) H. Copper readily unites with phosphorus.

**Chemistry.** Its carburet was not supposed to exist, but Priestley obtained it by passing the vapour of alcohol through a Copper tube; the discovery is confirmed by Van Marum. (b.) Boron, silicon, hydrogen, and nitrogen, do not seem as yet to have been united to this Metal.

(830.) I. Alloys of Copper are of frequent occurrence in the Arts. Alloys have also been formed with potassium, sodium, arsenic, iron, (with difficulty,) nickel, cobalt, manganese, zinc, (common brass,) cadmium, tin, bismuth, and lead; but in the last case the union is so imperfect that, by heating the alloy to such a temperature as to fuse the lead, it runs out leaving the Copper nearly pure. This is curiously seen in heating Roman coins.

(831.) K. Let it be remembered that almost all the Salts of Copper contain the black oxide of the Metal. The action of nitric Acid on Copper is very violent, nitrous Gas is evolved, and the solution produces a blue crystallizable Salt. No nitrate of the suboxide exists, as by the action of nitric Acid on the suboxide, one portion of Copper falls down in the metallic state, and the other portion receiving its oxygen, a solution of the proto-nitrate remains. Without heat, concentrated sulphuric Acid has no action on Copper, but at a boiling heat the Acid is partly decomposed. Sulphurous Acid Gas escapes, and a soluble sulphate is produced. The common blue vitriol of Commerce is a bisulphate. For a description of the numerous Salts of Copper, we must refer to the more complete Systems of Chemistry.

(832.) L. Solutions of Copper are changed to a deep blue colour by addition of ammonia. Prussiate of potassa gives a reddish brown precipitate, the hydrosulphurets a black, and gallic Acid a brown one. A plate of iron throws down the Copper in the metallic state.

(833.) The uses of Copper in the Arts are so numerous and varied, that many will occur to the recollection of every one. In Medicine, the sulphate has been cautiously administered, but is an active poison; in Surgery it is employed as an escharotic.

#### References to § 12.

(a.) Thenard, *Syst.* vol. ii. p. 381. (b.) *An. de Ch.* vol. xxx.; Chenevix, *Phil. Trans.* 1801; Proust, *An. de Ch.* vol. xxxii. p. 26; Oxides, Berzelius, *Phil. Mag.* vol. xli. p. 200; Phosphuret, Pelletier, *Mém. de Ch.* vol. i. p. 274, and vol. ii. p. 32.

### Sect. XIII.—Tellurium.

(834.) A. This Metal was discovered by Klaproth in one of the most productive of the ores of gold. The two Metals are found combined in the mines of Transylvania.

(835.) B. Tellurium is extracted by dissolving the gold-ore in nitro-muriatic Acid. The solution is diluted with water and pure potassa is added. Thus all the Metals are precipitated, together with a white powder, which is redissolved by an excess of the precipitant. This alkaline solution is again acidified by hydrochloric Acid; which throws down a precipitate. This powder is dried and heated with charcoal in a glass-retort. Metallic Tellurium is volatilized and forms brilliant metallic drops on the cooler surfaces of the retort.

(836.) C. In colour, this Metal is between tin-white and lead-grey, with considerable lustre, and a foliated texture. Extremely light, fusible below a red heat, and very volatile.

(837.) D. When heated in the open air, Tellurium undergoes combustion and is oxidated. The oxide of Tellurium is capable of performing the parts both of a base and of an Acid; so that if space permitted a full description of its properties, we ought to place the Telluric Acid as a Subsection.

(838.) E. Tellurium unites with chlorine, forming a white Solid.

(839.) F. G. Unexamined, except that the iodide forms a red aqueous solution.

(840.) H. A combination of Tellurium with hydrogen was discovered by Sir H. Davy in 1809, and called Telluretted Hydrogen Gas. It possesses slightly acid properties, and therefore might with propriety be called Hydro-Telluric Acid Gas. It unites also with sulphur and carbon.

(841.) I. The habits of Tellurium with other Metals are little known. It has been alloyed with potassium; but does not seem disposed to unite with mercury.

(842.) K. A few of the Salts with oxide of Tellurium as a base have been examined by Berzelius; these are the sulphate, hydrochlorate, and nitrate.

The same Chemist has also examined the tellurates, and described those of potassa, ammonia, lime, barytes, copper, iron, and lead.

(843.) L. Tellurium is recognised by its volatility; by being precipitated as a white powder from its solution in nitric Acid; by giving also an orange brown precipitate with Hydrosulphuric Acid Gas.

(844.) M. Noue.

#### References to § 13.

Klaproth, *Crell's An.* vol. i. p. 91; and 1799, vol. i. p. 275; Davy, *Phil. Trans.* 1801, p. 16; Berzelius, *Nich. Jour.* vol. xxxvi. p. 129.

### Sect. XIV.—Lead.

(845.) A. Of the first discovery of Lead we have no record, but it has been known from the very earliest times, as we find it frequently mentioned in the Mosaic writings. The Alchemists found reasons for identifying it with Saturn, under whose name they spoke of it, and by whose symbol they represented it. Lead is rarely found native, but it forms a part of several compound minerals. Its sulphate, carbonate, phosphate, chromate, and molybdate, are found in greater or less abundance; but it is from the sulphuret (galena,) a very abundant ore, that this useful Metal is principally obtained.

(846.) B. The processes for obtaining Lead from its native sulphuret differ in some particulars, which depend upon the nature and richness of the ore. In general, the ore is triturated and washed in running water to remove as much as possible of the earthy impurities. It is then roasted to drive off a part of the sulphur, and subsequently fused with charcoal or lime, for the complete reduction of any oxide that may be formed; or for the final separation of any sulphur which may remain in combination. The galena is however often sufficiently rich in an accompaniment of silver, to make it worth while to submit it to a further process for the extraction of that Metal. It is remarked, that that galena which has a fine-grained fracture, exhibiting small, bright, curvilinear facettes, is the richest in precious Metal. (a.) (b.)

(847.) C. The colour of Lead is a bluish white.

**Chemistry.** When in fusion it is bright like quicksilver, but rapidly tarnishes and becomes covered with a crust of oxide. By exposure to air it becomes dim in a few hours, acquiring a thin surface consisting of a carbonated oxide, and then undergoes no further change. Lead can scarcely be said to make any impression on the nerves of taste, but it develops a slight smell upon friction. It produces a bluish streak upon white substances. Few Metals are less hard, for it yields to the nail. Its tenacity is by no means considerable, for, according to Mr. Rennie's experiments, a wire 25 inches in diameter supported only 114 lbs. (c.) The ductility of Lead is not great, though it may with care be formed into wire; and it scarcely can be said to possess any elasticity; but its malleability is rather considerable. According to Newton, the fusing point of Lead is about 540° Fahrenheit. Irvine found it 594°, (d.) and Crichton, of Glasgow, states it to be 612°. (e.) By increased heat, the Metal boils and is volatilized. By slowly cooling, it may be obtained in the crystalline form. Mongez describes these as quadrangular pyramids, and Pajot de Chormes obtained a polyhedron of 32 faces arising from the aggregation of six quadrangular pyramids. (f.)

(848.) D. Chemists have, in general, described Lead as uniting with oxygen in only three proportions. Berzelius, however, describes four oxides of lead.

1. The first, which he terms the suboxide, is the dark powder which gradually forms upon the surface of metallic Lead when left exposed to the air. (g.) Dulong obtained the same oxide by distilling oxalate of Lead to a dry powder in a glass-retort. Carbonic Acid and carbonic oxide Gases are evolved, and the suboxide remains as a dark grey powder.

(849.) 2. The next, or yellow oxide of Lead, is best obtained by precipitation from the addition of carbonate of potassa to a solution of Lead in nitric Acid. The powder as it first falls is white, but being dried, and heated nearly to redness, it takes its true yellow colour. This substance is without taste or smell, is insoluble in water, but soluble in potash or Acids. By heat it easily vitrifies, and by a considerable heat it is capable of volatilization, but if so heated with free exposure to the air the surface passes on to a red colour. (h.) (i.)

The *Massicot* of commerce, is in fact, the yellow oxide of Lead formed by exposing Lead to heat, and removing the oxide as fast as it forms upon the surface of the fused metal. This powder has at first a dusky-green colour, being a mixture of true oxide and metallic Lead, but by longer exposure to heat in an open vessel more oxygen is absorbed, and complete massicot is formed.

*White Lead*, so much used as a pigment, is a compound containing the yellow oxide of Lead and carbonic Acid. It is formed by exposing thin plates of Lead to the vapour of hot vinegar.

(850.) 3. The next oxide of Lead is of a bright red colour, and is known in the Arts by the name of *Minium*, or *Red Lead*. It is easily formed by exposing finely powdered massicot in such a furnace, that the flame may constantly play upon the powder which is constantly stirred so as to expose fresh surfaces. The process is continued forty-eight hours. (k.)

Minium is a tasteless powder of very high Specific Gravity; by exposure to a red heat it parts with a portion of its oxygen and fuses into a dark brown glass. It is acted upon by Acids, but in every case seems to

undergo decomposition, and to be reduced to the state of the yellow oxide. Indeed there is no combination known in which the red oxide of Lead retains its constitution unchanged.

(851.) 4. The highest oxide of Lead is a puce-coloured powder, formed by dispersing the yellow oxide through a mass of water, and then passing a current of chlorine through the Liquid. There results a soluble hydrochlorate of Lead which may be separated by washing, and the peroxide of Lead is an insoluble powder. Such is Proust's method. It is, however, better to put one part of the red oxide (minium) into a flask with five or six parts of diluted nitric Acid, containing equal proportions of Acid and water. Heat the Liquid almost to ebullition and agitate it from time to time. Thus a soluble nitrate of the yellow oxide is formed, and the peroxide of Lead, insoluble both in water and nitric Acid. That is to say, one portion of the minium takes oxygen from the other portion, and passes to the state of peroxide, while the latter portion, being reduced to the state of massicot, (2 oxides,) forms the soluble nitrate of Lead. The oxide is to be well washed when the process is completed and carefully preserved in an air-tight phial.

The atomic constitution of these oxides of Lead present some difficulties which we have not space to discuss.

(852.) E. When Lead is placed in chlorine Gas, it does not undergo visible combustion, but the Gas is absorbed, and chloride of Lead is formed. This chloride is, however, more easily obtained by precipitation from adding a solution of common salt to a solution of nitrate of Lead. It is then found in the form of delicate, white, plumose crystals, which are, in fact, hexahedral prisms. By heat, these crystals are fused into pure anhydrous chloride of Lead: the *plumbum corneum* of early authors.

There exists also a subchloride of Lead, a white, insoluble powder, which takes a fine, yellow colour by application of heat. It is formed by decomposing a small quantity of common salt in a great excess of litharge diffused through water.

(853.) F. If hydrofluoric Acid be poured into a solution of acetate of Lead, a precipitation takes place in the form of brilliant laminae insoluble in water, very soluble in nitric, hydrochloric, hydrofluoric Acids, and fusible at a red heat. This is considered, by some, the fluoride of Lead, and not the hydrofluat, because of its insolubility in water.

(854.) G. By heating iodine and Lead together, the iodide of Lead is readily formed. It is a fine, yellow, waxy-looking substance. The same compound is produced as an insoluble precipitate whenever a solution of any hydriodate is added to a solution of a Salt of Lead. This precipitate is of a beautiful, citron colour.

(855.) H. The combinations of Lead with azote, hydrogen, boron, or silicon, are as yet unknown.

(856.) *Carburet of Lead* is a black powder, very easy of reduction, formed by heating together a mixture of finely-powdered charcoal and oxide of Lead in a closely-luted crucible. It may also be formed by moderately heating a precipitated prussiate of Lead; in this case, nitrogen escapes and carburet of Lead remains.

(857.) *Seleniuret of Lead*. When selenion and Lead are heated together, an intimate union takes place, and more heat is evolved. A grey, porous mass is formed

Chemistry, which is not fusible at a red heat, but is soft, and takes a silvery polish. (l.)

(858.) *Phosphuret of Lead* may be formed by dropping bits of phosphorus into melted Lead; or by heating in a crucible equal parts of glass of phosphorus and Lead-filings. This substance may be cut with a knife, but is not malleable. Its colour is silver-white, inclining to blue, but it tarnishes by exposure to air. (m.)

(859.) *Sulphuret of Lead* is easily formed by dropping pieces of sulphur into melted Lead, or by placing alternate layers of the two substances in a crucible in continued proportion, three of Lead to one of sulphur, and giving a moderate heat. Sulphuret of Lead thus formed is of a deep blue-grey colour of considerable brilliancy, less fusible than pure Lead, and very brittle. Heat does not decompose it; oxygen is not acted upon by it at an ordinary temperature; but by a moderate elevation of temperature it passes into sulphate of Lead, and sulphurous Acid, while by a further increase of temperature, a part of the Lead is reduced. This is identical with the mineral galena.

Professor Thomson states, that, "besides the common sulphuret of Lead, there occurs another occasionally, lighter in colour and more brilliant, which burns in the flame of a candle, or when put upon burning coals, emitting a blue flame. It contains at least 25 per cent. of sulphur. It is, therefore, a *Bisulphuret* of Lead. This variety has not hitherto been noticed by Mineralogists, neither has it been made artificially by Chemists." (n.)

(860.) I. Lead combines readily with several other Metals. When fused with gold, it enters into intimate combination, and when even small in quantity, it greatly impairs the colour and ductility of the nobler Metal. With silver it forms a very fusible compound, but of inferior tenacity and hardness. The same is true of the alloy of Lead and *platina*. The alloy of Lead and copper is a brittle, grey substance. It had been thought that iron could not be combined with Lead, but Muschenbroeck united 134 parts of Lead with 400 of iron, and formed a hard alloy, but inferior to iron in tenacity. Morveau showed, that when the two Metals are heated together, two distinct alloys are formed, the one at the top of the crucible, containing very little Lead, the other a button of iron at the bottom, but combined with a small quantity of Lead. (o.) This Metal readily unites with *potassium* and *sodium*. Gmelin formed the alloy of *cobalt* and Lead, by placing powder of cobalt between plates of Lead, and submitting them to heat in a crucible well covered with charcoal. (p.) Gmelin also examined carefully the alloys of Lead and zinc; the Metals seem to unite in almost every proportion. (q.) *Bismuth* was combined with Lead by Muschenbroeck, and formed a brittle alloy. The alloy of Lead and *arsenic* is brittle, having a foliated structure. *Mercury* dissolves Lead, and the amalgam seems to retain its physical properties much in proportion to the quantities of its respective ingredients. When the Lead is in such quantity as to produce a mass nearly solid, certain crystalline facettes are perceptible.

(861.) K. Acids for the most part act upon Lead or its oxides. The Salts thus formed have a sweet taste. One oxide alone, the yellow, seems to form the base of its Salts; for if the other oxides be employed in solution, oxygen is evolved, and a Salt of the yellow oxide results.

*Cold Sulphuric Acid* has scarcely any action upon Lead, but when boiled upon it, there is an evolution of sulphurous Acid Gas, the metallic oxide is formed, and, combining with the sulphuric Acid, produces a white pulverulent substance, which is sulphate of Lead with some excess of Acid. A portion, also, is dissolved in the Acid, and may be reduced to acicular crystals, by evaporation. A neutral sulphate is, however, more regularly formed by adding a solution of any Salt of Lead to a solution of an alkaline sulphate. The white precipitate, which is sulphate of Lead, is almost insoluble in water.

(862.) *Sulphurous Acid* does not act on Lead; but if the red oxide be placed in this Acid, a saline mass is formed, consisting of both sulphate and sulphite of the yellow oxide. Sulphite of Lead is formed, also, by immersing the white oxide obtained from the nitrate in sulphurous Acid.

(863.) *Hydrochloric Acid* has but slight action upon Lead even when heated. When muriatic Acid is digested in the red oxide, the Acid is partially decomposed, as also the oxide; hydrogen from the former unites with a part of the oxygen from the latter, so that a chloride of the yellow oxide results; the excess of Acid serving as a solvent, the Salt ultimately crystallizes in delicate, silky prisms. (Vide E.) But to obtain this neutral muriate most readily, let a soluble Salt of Lead be added to any alkaline muriate; acetate of Lead, for instance, to muriate of soda. This Salt is soluble in 30 parts of water, and readily fuses by heat.

(864.) *Nitric Acid* forms several compounds with Lead, so as to produce rather a complicated series of Salts. Nitric Acid, slightly diluted, dissolves Lead with rapid evolution of nitrous Gas. From this solution, or from a solution of the yellow oxide in Nitric Acid, octohedral, diaphanous crystals are easily obtained. This seems to be the anhydrous nitrate of the yellow oxide. (r.) The other combinations of these substances have been examined by Chevreul and Berzelius, and to their Memoirs we must refer the reader. (s.) They are well described in Thomson's *System of Chemistry*.

(865.) *Phosphoric Acid* acts slowly upon Lead. But the phosphate of Lead, a flaky white precipitate, is easily formed by adding a solution of phosphate of soda to nitrate or acetate of Lead. This substance is insoluble in water, soluble in nitric Acid, and is decomposed by the muriatic and sulphuric Acids. Berzelius has described, also, a superphosphate and a subphosphate. (t.)

(866.) *Phosphite of Lead* is formed by adding a hot, concentrated solution of muriate of Lead to a solution of phosphite of ammonia, the precipitate is a flocculent, white powder.

(867.) An insoluble, white precipitate of *Borate of Lead* is formed by adding a solution of borax to nitrate of Lead.

(868.) *Carbonate of Lead* is found native, or is readily obtained by adding an alkaline carbonate to any solution of a Salt of Lead.

The oxides of Lead have never, in common language, been considered as performing the part of Acids, nevertheless they have, in general, a strong degree of affinity for the earthy oxides. Solutions of potash, or soda, will dissolve and hold in solution a portion of oxide of Lead. Lime, when boiled with it in water, does the same, and minute crystals may be obtained by evaporation. By fusion, all the earths unite with the oxides

**Chemistry.** of Lead forming differently-coloured enamels; and of all the metallic oxides, that of Lead forms the strongest flux for promoting the vitrification of earthy substances. So strong is the affinity of oxide of Lead for the Acids, that it will decompose some neutral Salts when dry. Thus if oxide of Lead and muriate of ammonia be triturated together, ammonia is evolved, and by the aid of heat a complete decomposition may be effected. Muriate of soda is capable of a similar decomposition.

(869.) L. Numerous characteristics distinguish Lead and its Salts; the latter, if soluble at all, give a colourless Liquid. They have a sweet taste, and are strongly styptic. Hydrosulphuret of potash, sulphuretted hydrogen, and, in short, sulphur in any of its forms, produces a copious black or deep-brown precipitate. Prussiate of potash, gallic Acid, and infusion of galls, all produce white precipitates. Zinc precipitates the Lead in a pure, metallic state. Sulphate of soda is used as a test of Lead producing a white precipitate. Hydriodate of potash produces a beautiful, bright, yellow-coloured precipitate. Vauquelin has shown that the precipitates thrown down from the Salts of Lead by the alkalis are subsalts. (u.) The most satisfactory proof that a precipitate contains Lead, is obtained by reducing it by the blow-pipe on charcoal. The polyhedral form which the irreducible, enamel-looking globule assumes upon cooling, after it has been fused by the blow-pipe on charcoal, is a good proof of Lead which has been precipitated by a phosphate.

"The uses of Lead are extensive. As it is flexible, easily reduced to thin sheets, and easily united by solder, it is used in making pipes for conveying water, large boilers, and vessels of different kinds. It is cast into thin sheets for covering buildings. Its oxides are used as paints. They are also employed in the manufacture of the finer kinds of glass, to which they communicate density, a higher refractive power, a greater equality of texture, and a greater susceptibility of polish: hence, they enter into the composition of the pastes which imitate gems. They form, in combination with earthy matter, the glazing of the inferior kinds of earthenware. There is some reason to doubt, whether the use of Lead in pipes for conveying water, or in vessels for containing it, be altogether safe; Lead, immersed in water, is covered at length with a white crust of oxide or carbonate, and this Metal is the most insidious, and, at the same time, one of the most destructive of the mineral poisons. In water, however, which has been conveyed through pipes of Lead, no trace of the Metal can be discovered by the most delicate test, sulphuretted hydrogen. Even water kept in cisterns of Lead, where the exposure to the air is more free, seems not to have, in general, any sensible impregnation; this may arise from the deposit of earthy matter from the water covering the Lead. The observations of Guyton too, on the effect of the presence of a little saline matter in preventing its action on Lead, may serve to explain how the practice of keeping water which is used as drink in cisterns of Lead, is not more injurious than it appears to be. Some facts appear to prove, that river water is more liable to receive an impregnation from leaden vessels than spring water is, probably from the Salts in the former being chiefly muriates, while in the latter they are sulphates or carbonates. The use of earthenware glazed with oxide of Lead is hazardous, as the glazing is soon eroded by any acid liquor, and a noxious impregnation commu-

nicated; and many fatal accidents have occurred from the use of Lead in the fabrication of vessels in which wine, cider, and other fermented liquors, are prepared or kept."

Minium and massicot have been already noticed. (D.) *Litharge*, another common preparation of Lead, is supposed to contain the yellow oxide, with, perhaps, the admixture of some carbonic Acid; it is formed during the process of cupellation by directing a strong current of air upon the surface of the fused Lead which thus carries off the oxide in a semivitrified, or crystalline state, in fine scales as fast as it is formed. If litharge be fused by a stronger heat into a compact mass, it goes by the name of *Glass of Lead*.

In consequence of the sweet taste of the Salts of Lead, they have at times been employed to correct the flavour of bad wines. This most pernicious adulteration is readily detected by what is generally called *Hahneman's Wine Test*, having the advantage of precipitating Lead but not iron. "It is prepared from sulphuret of lime (formed by exposing equal parts of sulphur and oyster-shells to a white-heat for 15 minutes) and supertartrate of potash. 120 grains of the sulphuret and 180 of the supertartrate are put into a bottle, which is to be filled with 16 ounces of water that has been previously boiled and suffered to cool. The liquor having been repeatedly shaken, is to be poured off clear into phials which hold about one measured ounce; into each of which about 20 drops of muriatic Acid has been put; and they are well corked. One part of this solution mixed with three parts of the suspected liquor will discover, by a black precipitate, the smallest quantity of Lead, while it does not precipitate iron; the tartaric and muriatic Acids retaining iron in solution when combined with sulphuretted hydrogen." (v.) Burgundy, and all wines which hold tartar in solution, will not retain an adulteration of Lead, as the tartrate is insoluble. Lead taken internally, is an active poison. Small quantities of the acetate are sometimes given as a styptic in cases of internal hemorrhage. Its solution is employed as a sedative application to inflamed surfaces and scrofulous sores. When greatly diluted, it forms a good eye-water. *Gonlard's Extract*, the sub-acetate, is indeed a valuable article in Pharmacy. The deleterious effects of Lead may be seen in the specific disease which afflicts house-painters, and has the name of *Colica Pictonum*. A disease much singular prevailed formerly in the cider Countries, from placing the cider in leaden vats. Its evil effects are chiefly of a paralytic form, when taken for some time in small quantities. A large dose will act as a poison: the best antidote for any one that cannot be ejected from the stomach, is a quantity of sulphate of soda dissolved in water.

#### References to § 19.

(a.) Aikin, *Ch. Dict.* art. Silver. (b.) Nicholson, *Jour.* vol. xv. p. 1. (c.) *Phil. Trans.* 1818, p. 126. (d.) *Chemical Essays*, p. 35. (e.) *Phil. Mag.* vol. xvi. p. 49. (f.) *Jour. de Ph.* vol. xxxviii. p. 53. (g.) *An. de Ch.* vol. lxxxvii. (h.) Bucholz, Gehlen's *Jour.* vol. v. p. 259. (i.) Berzelius, *An. de Ch.* vol. lxxviii. p. 11, and vol. lxxix. p. 121. (k.) Watson, *Essays*, vol. iii. p. 338. (l.) Berzelius, *An. de Ch. et de Ph.* vol. x. p. 245. (m.) Pelletier, *An. de Ch.* vol. xiii. p. 114. (n.) *Syn.* vol. i. p. 449, Ed. 6. (o.) *An. de Ch.* vol. lviii. p. 47. (p.) *An. de Ch.* vol. xix. p. 357

Chemistry. (g.) *An. de Ch.* vol. ix. p. 95. (r.) Thomson, Nich. *Jour.* vol. viii. p. 288. (s.) *An. de Ch.* vol. lxxxiii. p. 1, 57, vol. lxxxiv. p. 1. (t.) Berthier, *Jour. de Mines*, No. 182; Berzelius, *An. de Ch. et de Ph.* vol. ii. p. 160. (u.) Nich. *Jour.* 4to. vol. iii. p. 473. (v.) Crell's *Chem. Jour.* vol. iii. p. 61.

## METALS. CLASS V.

### Sect. I.—Mercury.

(870.) A. The early history of this Metal is entirely involved in the obscurity of distant Ages. Its uses in the separation of other Metals are among the earliest recorded metallurgic processes. (a.)

(871.) B. The ores of Mercury are numerous. The process by which the pure Metal is chiefly obtained is by putting the richest ore, carefully picked, into retorts with some lime just slaked by exposure to air. Heat is applied, and the Mercury is condensed in a cool receiver.

(872.) C. This is the only Metal permanently fluid at our ordinary atmospheric temperatures. It freezes at  $-39^{\circ}$ , or  $-40^{\circ}$  Fahrenheit; at  $680^{\circ}$  on the common Mercurial scale, or  $662^{\circ}$  on that scale corrected, it boils, and rapidly distils over. Its vapour has high expansive force.

(873.) D. Mercury undergoes oxidation by agitation in a bottle with atmospheric air. The oxide so formed was called *Æthiops per se*, by Boerhaave. This black oxide is, however, better obtained by boiling calomel with an excess of caustic alkali in solution.

Another oxide is formed by exposing the Metal, for several days, to a high temperature, in a flat glass-vessel freely exposed. The red oxide so obtained was formerly called *Precipitate per se*. The oxides of Mercury are reduced by mere exposure to heat in a retort. The two oxides of Mercury are true protoxide and deutoxide.

(874.) E. Mercury readily forms two chlorides. Calomel is the protochloride, and Corrosive Sublimate the deutochloride of this Metal.

(875.) F. Unexamined.

(876.) G. There are two iodides of Mercury. The protiodide is formed by mixing a solution of the protonitrate of Mercury with the hydriodate of potassa. The deutoiodide by mixing the same hydriodate with a solution of any deuto-salt of Mercury.

(877.) H. Mercury combines with sulphur, forming a sulphuret and bisulphuret. The latter, known by the name of *factitious Cinnabar*, is formed by fusing sulphur with six times its weight of mercury, and collecting the sublimate produced in close vessels. When reduced to fine powder, this same substance is *Vermilion*. *Æthiops Mineral* is formed by triturating together equal parts of Mercury and sulphur. Mr. Brande has shown that it is a mixture of sulphur and bisulphuret of Mercury. (b.)

(878.) I. Of these substances, selenion alone has been combined with Mercury.

(879.) K. The sulphuric, nitric, and some other Acids dissolve Mercury. Two distinct classes of Salts are formed by its respective oxides. In a more extended Treatise these ought all to be described. Here, however, that is not possible; and as it is obvious to the reader, that in thus abbreviating our description of this Metal, we are treating of it far less fully than many of the other Metals, and especially than that described in

the last section, we state once for all, in apology to those who may make the remark, and with justice, that the inequalities of that sort, which are considerable, in this Treatise, arise from circumstances which the author has not been able to control.

(880.) We must not, however, omit to notice a curious detonating compound of Mercury described by Mr. Howard. (c.) It is formed by dissolving 100 grains of Mercury in a fluid ounce and half of nitric Acid, of Specific Gravity 1.3; and when cold, pouring the solution gradually into two ounces of alcohol. Specific Gravity 0.849. The mixture is then to be gently heated in a flask, or retort, over a lamp, till a brisk effervescence ensues. A dun-coloured precipitate falls down, which is to be most carefully dried over a water-bath; and this is the fulminating Mercury. This compound will bear a heat somewhat above  $212^{\circ}$  without explosion; but any further elevation of temperature, or friction with hard substances, or percussion, occasions instant and violent explosion. From silver, a similar, but still more violent compound is obtained. See FULMINATING POWDERS in our *Miscellaneous Division*. M. Liebig proved, (d.) that this substance is a Salt containing a peculiar Acid; and MM. Gay Lussac and Liebig have made a further analysis of that Acid. (e.) From their experiments, the Acid appears to consist of cyanogen and oxygen, so as to be a true cyanic Acid.

(881.) L. Solutions containing Mercury give a white precipitate with prussiate of potassa, a black one with hydrosulphates; a white one with hydrochloric Acid; orange-yellow with gallic Acid; and a plate of copper throws down the Metal pure. A neat test of Mercury is mentioned in the very valuable Work on Medical Jurisprudence by Paris and Fonblanque. Place a drop of a Liquid, suspected to contain Mercury, on a polished plate of gold. Touch the moistened surface with the point of a knife; if Mercury be present, the point touched instantly becomes white from the formation of an amalgam of Mercury and gold.

(882.) M. Mercury has many uses in the Arts, in Metallurgic processes, and in Medicine.

#### References to § 1.

(a.) Watson's *Chemical Essays*. (b.) *Journal of Science*, vol. xviii. p. 294; also Guibourt, *An. de Ch. et de Ph.* vol. i. (c.) *Phil. Trans.* 1600. (d.) *An. de Ch. et de Ph.* vol. xxiv. (e.) *An. de Ch. et de Ph.* vol. xxv.; Donovan, *An. Phil.* vol. xiv. p. 244; Sefstrom, *An. Phil.* vol. iii. p. 335; Payssé, *An. de Ch.* vol. li. p. 202. Bergman, *Opusc.* vol. iv. p. 281; Rose, *Gehlen's Jour.* vol. vi. p. 28; Zabouda, *Jour. de Ph.* vol. ix. p. 383; Davy, *Phil. Trans.* 1811. p. 26; Pelletier, *An. de Ch.* vol. xiii. p. 122; Gay Lussac and Thenard, *Rech.* vol. i. p. 222.

### Sect. II.—Nickel.

(883.) A. Nickel was first recognised as a distinct Metal by Cronstadt in 1751, and his experiments were confirmed by Bergman in 1775. Kupfer-nickel, *false copper*, was the minor term for the ore, and the latter word was retained by Cronstadt as its distinctive name. It is found as a very impure metallic alloy, and in the state of an oxide. It is also considered the colouring matter of Chrysoprase.

(884.) B. The analysis of Kupfer-nickel is complicated, but an easy method of obtaining the pure Metal is proposed by Thomson. Dissolve the Nickel of Com-

**Chemistry.** merce (speiss) in sulphuric Acid, adding a small quantity of nitric Acid to promote oxidation. By concentration, green crystals of sulphate of Nickel are obtained; and, for further purification, some of the first formed and purest are washed, and again dissolved in water, and submitted to a second crystallization. By adding an alkali to a solution of these in water, pure oxide of Nickel is obtained. Let this be mixed with three per cent. of resin, formed into a paste with oil, and exposed to a forge-heat in a charcoal crucible, a button of pure metallic Nickel is obtained.

(885.) C. Pure Nickel is nearly as white as silver, but with a slight cast of yellow. It is malleable, and rather softer than iron. Its Specific Gravity, when fused, is 8.03, but by hammering it, it is brought to 8.82. Its fusing point is at least 160° of Wedgewood. Nickel possesses permanent magnetic properties, and, according to Lampadius, its energy is to that of iron as 35 to 55.

(886.) By exposure to heat, Nickel tarnishes but does not oxidate. If, however, the Metal is dissolved in nitric Acid, the precipitate given by potassa after exposure to a red heat, is the protoxide and of a bluish-brown colour. Thenard obtained the next, a hemideut-oxide, by passing a current of chlorine through water holding protoxide of Nickel suspended in it; a portion is dissolved, and the remaining black powder is the hemideut-oxide of this Metal.

(887.) E. Nickel does not instantly combine with chlorine, but by leaving the substances in contact, a chloride may be formed; a more ready process, however, is to expose the muriate to a red heat.

(888.) F. Unknown.

(889.) G. The iodide of Nickel, a greenish precipitate, is formed by adding hydriodate of potassa to a solution of the sulphate or nitrate of the Metal.

(890.) H. Nickel has been united to sulphur, phosphorus, selenium, and carbon, but does not combine with nitrogen or hydrogen. Of its habitudes with boron, or silicon, we are ignorant.

(891.) I. Nickel combines with gold, copper, tin, and arsenic, forming brittle alloys, but its compounds with silver and iron are ductile. Arsenic entirely destroys its magnetic properties, as it also does those of iron and cobalt.

(892.) K. Both Nickel and its oxides are readily soluble in nitric Acid with heat, and a nitrate is obtained in rhomboidal prisms, which, according to Bergman, first deliquesce, and finally effloresce, and fall to powder. Proust describes a subnitrate also, and Thenard a double nitrate of Nickel and ammonia.

Sulphuric Acid dissolves the oxide, and also the Metal; if aided by the addition of a few drops of nitric Acid the sulphate readily crystallizes. Sulphate of potash and Nickel, of ammonia and Nickel, and of iron and Nickel, have also been described.

Hydrochloric Acid scarcely attacks the Metal, but dissolves the oxide, and a crystalline hydrochlorate is produced, with properties like those of the nitrate. The following Acids do not attack the Metal, but produce precipitates of insoluble Salts, on the addition of their neutral Salts to neutral solutions of Nickel. Carbonic, phosphoric, (and this has a slight action on the oxide,) boracic, selenic, (but the biseleniate is soluble,) and molybdic.

The oxalic Acid attacks Nickel if slightly heated, and a greenish, insoluble oxalate is deposited. It may

also be produced by dropping oxalic Acid into a Salt of Nickel in solution. Acetic Acid also dissolves Nickel, and a very soluble Salt results. No precipitate is produced by adding benzoate or succinate of ammonia to solutions of Nickel; hence these Salts are considered soluble. The arseniate also is soluble; but the chromate, formed by suffering chromic Acid to act upon the carbonate, gradually deposits itself in a pulverulent form.

All the Salts of Nickel are of a green colour, and appear to contain the protoxide, which is also soluble in ammonia. On this property Thenard has founded his process for separating Nickel from cobalt. (*An. de Chim.* vol. 1.) A solution of the two Metals is precipitated by an alkaline carbonate. By the addition of oxymuriate of lime, the cobalt is converted into the peroxide. Ammonia will now take up the oxide of Nickel only, which may be regained by evaporation.

Nickel is soluble also in ammonia.

(893.) L. In neutral solutions of Nickel, hydro-sulphuric Acid Gas produces no change, but hydrosulphate of potash gives a black precipitate. Prussiate of potash, a white or greenish one; and infusion of galls gives, with some Salts, a grey precipitate, but, according to Thomson, with the sulphate none at all. The caustic alkalis produce white, and their carbonates apple-green precipitates. No Metal produces one precipitation.

(894.) M. The only purpose to which Nickel has been applied is in the formation of magnetic needles, for which, if plentiful, it might sometimes be useful where steel would rust. From some recent experiments of Stodart and Faraday, *Quarterly Journal*, vol. ix., the alloy of Nickel and iron would be serviceable in the Arts, being less liable to rust than common iron; but it is singular that Nickel alloyed with steel increases the tendency to rusting. By far the greater part, and, until lately, it was thought that all the meteoric stones which have fallen from the atmosphere contained Nickel. Laugier (*Mém. de Muséum*, vol. vi.) asserts chromium to be a more constant ingredient; but, be this as it may, several masses of native metallic iron, which from their situation upon the surface of the earth appear to be of meteoric origin, contain more or less Nickel. The blades of the knives used by the Esquimaux tribe, found in the late Northern voyages of discovery, were of this kind.

#### References to § 2.

Cronstadt, *Stockholm Trans.* 1751 and 1754; Berg. *Opusc.* vol. ii.; Fourcroy, *Disc. Prélim. Ecole de Mines*; Bucholz, *Gehlen's Jour.* vol. ii. and vol. iii.; Richter, *Gehlen's Jour.* vol. iii.; Tourte, *Gehlen's Jour.* vol. viii.; Phillips, *Phil. Mag.* vol. xvi.; Proust, *Jour. de Phys.* vol. lvii.; Thenard, *An. de Ch.* vol. i.; Proust, *An. de Ch.* ix.; Tupputi, *An. de Ch.* vol. lxxviii.; Lampadius, *An. Phil.* vol. v.; Tupputi, *An. de Ch.* vol. lxx.; Laugier, *An. de Ch. et de Ph.* vol. ix.; Berthier, *An. de Mines*, vol. iv.; and *An. de Ch. et Ph.* vol. xiii.

#### Sect. III.—Osmium.

(895.) A. Osmium was so called by Professor Tennant from the peculiar and pungent smell (*ὀσμή*) of its volatile oxide. This smell, according to Fourcroy and Vauquelin, is similar to that of chlorine; and to their examination of this substance we owe some information, though they confounded this Metal and iridium toge-



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ther. The existence of this Metal in a native alloy with iridium, among the grains of crude platinum, has been already noticed.

(896.) B. To obtain metallic Osmium, the alkaline solution mentioned in the section on iridium, is to be mixed with sulphuric Acid, and submitted to distillation. The oxide of Osmium passes over with some water; metallic mercury is agitated with this solution, and abstracts to Osmium, forming an alloy. By subsequent distillation, the mercury is separated, and the Osmium remains.

(897.) C. Osmium is a dark-grey powder, and as it has never yet undergone sufficient heat to reduce it to a mass, its physical properties are quite unknown.

(898.) D. When Osmium is heated with exposure to air, it oxidates and sublimates, but it is very probable that the pure Metal is not volatile. Oxide of Osmium may be readily procured by mixing the black powder with nitre, and distilling at a low heat. Oxide of Osmium rises into the neck of the retort in the form of an oily fluid, which by cooling becomes a solid, semitransparent mass, soluble in water. According to Vauquelin, pure oxide of Osmium exists in the form of transparent crystals, having a strong and caustic taste. Very soluble in water, and capable of blackening animal and vegetable substances. There is strong reason for suspecting that oxide of Osmium enters into combination with alkalis.

(899.) E. With chlorine, Osmium combines, appearing at first to melt, and assuming a green colour, and, finally, forming a brownish-red liquid.

(900.) F. G. H. Unknown.

(901.) I. Osmium has been alloyed with gold and copper.

(902.) K. On this head also very little is known by direct experiment. According to Tennant, Osmium resists the action of all Acids; but according to Vauquelin, it is soluble in the hydrochloric and nitro-muriatic; but of any Salts with oxide of Osmium as a base, we are as yet ignorant.

(903.) L. Solutions of oxide of Osmium become yellow by the addition of ammonia and carbonate of soda. Magnesia produces no effect, but potassa and lime produce yellow precipitates. The most striking test of Osmium is infusion of galls, which produces a blue colour in solutions of this Metal. If iridium also is present, the infusion of galls first destroys the red colour of the iridium in solution, and then develops the beautiful blue of the oxide of Osmium. Copper, tin, zinc, and phosphorus cause a metallic precipitation.

(904.) M. None.

#### References to § 7.

Tenant, *Phil. Trans.* 1804; Fourcroy and Vauquelin, *An. de Ch.* vol. 1; Vauquelin, *An. de Ch.* vol. lxxxix.

### METALS. CLASS VI.

#### Sect. I.—Silver.

(905.) A. Silver has been known and employed from the very earliest times. There are several ores of Silver in which it is combined with sulphur, with hydrochloric Acid, with antimony, arsenic, and mercury.

It is also found native, but not in a state of perfect purity, and from this source the first knowledge of the Metal would probably arise.

(906.) B. The rich ores of native Silver found at Konigsberg, are fused with an equal weight of lead, by which an alloy is formed, and finely purified by cupellation. The Freyberg ores, which contain but little Silver mixed with much pyrites, are mixed with common salt and roasted in the reverberatory furnace. The frit is then pulverized and washed; and by the addition of mercury an amalgam is formed, which is drained from the earthy and saline matters. It is then submitted to pressure in a bag, by which means the liquid mercury is separated, and the more solid alloy remains for final purification, by distilling off the remaining mercury in heated earthen retorts. In Mexico and Peru the process is nearly the same.

Silver is also obtained in considerable quantities from some varieties of galena, native sulphuret of lead.

For Chemical purposes, pure Silver is best obtained by a process recommended by M. Gay Lussac. (a.) Precipitate the Silver from its nitrate by a plate of copper; digest the precipitate in a weak solution of nitrate of Silver; by which any adhering copper is taken up, and pure Silver deposited in its place.

(907.) C. Silver is the whitest Metal at present known, and capable of receiving a very high degree of brilliancy from the burnisher. It has neither taste nor smell. Its hardness is superior to that of copper, but inferior to that of gold. Its Specific Gravity 10.39—10.51. Its ductility and tenacity are of the highest order, and in malleability it is inferior to gold only. It may be beaten out into leaves of one hundred-thousandth of an inch in thickness. It fuses at a full red heat, which has been estimated at about 1000° Fahrenheit, or according to Dr. Kennedy, at 22° Wedgewood. By a greatly increased heat, it is capable of volatilization. This is effected either by the flame of oxygen and hydrogen from the Gas blowpipe, or as Vauquelin found, by a current of oxygen alone upon charcoal. By slow cooling and pouring off some portion while still fluid, four-sided pyramidal crystals may be produced.

(908.) D. By exposure to the air or to water, Silver does not undergo oxidation, but by long continued heat in an open vessel it may be converted into a greenish-brown oxide: Galvanic Electricity and the common Electric discharge produce the same effect. The same oxide is produced by precipitating a solution of Silver in nitric Acid with lime-water. This oxide is insoluble in water, but soluble in several Acids, and in ammonia.

If the ammoniacal solution of this oxide be exposed to the air, a pellicle, consisting of a black powder, forms upon the surface, which Mr. Faraday considered a peculiar oxide; and from a repetition of his experiments, Dr. Thomson coincides with him in opinion.

(909.) E. When Silver is heated in chlorine, the Gas is gradually absorbed, and a chloride of Silver is obtained. It is easily formed also by adding any hydrochlorate, or a solution of chlorine, to a solution of nitrate of Silver, in which cases it instantly forms a white, curdy precipitate. This substance, formerly called muriate of Silver, is fused into a greyish mass, but undecomposed at a red heat; and this is the *horn Silver* of older Chemists and Mineralogists. It is soluble in ammonia, and decomposed by alkaline carbonates, while the pure alkalis and Acids have no effect upon it. Being a most definite compound, it is

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**Chemistry.** the usual state in which Silver is separated in analysis; and after a low red heat, its weight affords, by calculation, an accurate estimate of the Silver acted upon. The chloride is easily reduced, by fusion in a crucible with twice its weight of carbonate of potash or soda, a button of pure Silver resulting. It is also decomposed by trituration, or fusion with several of the Metals, (b.)

(910.) F. Unexamined.

(911.) G. By adding hydriodic Acid to a solution of nitrate of Silver, iodide of Silver is precipitated; it is yellow, insoluble in water or ammonia, but is decomposed by heating it with potash.

(912.) H. Silver does not combine with azote, hydrogen, carbon, boron, or silicon. Pelletier formed its phosphuret; and Berzelius is of opinion that two seleniurets exist. Silver appears to have a strong affinity for sulphur; the sulphuret is found native, and forms the tarnish which is so frequently seen upon Silver plate; this arises from the hydrosulphuric Acid Gas, which is produced by the decomposition of animal and vegetable matter daily going on. The discoloration of a tea-spoon with which an egg has been eaten, arises from the same cause.

(913.) I. Silver is alloyed with copper, for coinage, in England and most other Countries. It unites with iron, but with slight energy, for in cooling rapidly, globules of Silver are forced as it were from pores in the mass; and by slow cooling, the Metals are almost entirely separated in the order of their Specific Gravities, a mass of iron being found at bottom and Silver at the top. The same takes place with cobalt. Silver produces brittle alloys with zinc, arsenic, bismuth, lead, and tin; malleable ones with gold, copper, platinum, and mercury.

With nickel it refuses to unite.

(914.) K. Silver is acted upon by some of the Acids, but not by all. In the nitric, it is readily soluble, with the evolution of nitrous Gas. This solution gives to the skin, and to all animal matter, an indelible black stain. It is capable of crystallization, is soluble in alcohol, and a part of its Silver is reduced by exposure to light. It is decomposed by a red heat, and when fused by a moderate degree of heat, and cast into moulds, forms the common lunar caustic.

Sulphuric Acid acts on Silver only when heated, but at the same time the Metal must be in a minute state of division. Phosphoric Acid does not act on Silver, but the phosphate may be indirectly obtained. For a full description of the Salts of Silver, we must refer to more extended Treatises.

(915.) L. For the most part, the Salts of Silver are very sparingly soluble in water. They may be reduced, before the blowpipe, in charcoal. Solutions of Silver are precipitated by muriatic Acid, or the muriates. By sulphate of iron, the Silver is precipitated in the metallic state. By a plate of copper, the Metal is thrown down nearly pure. Prussiate of potash gives a white, and the alkaline hydrosulphurets a black precipitate. In some of the saline solutions of Silver, according to Thomson, gallic Acid causes a yellowish-brown precipitate.

(916.) M. The alloy of Silver with copper for coinage in England, is  $\frac{11}{12}$  of Silver to  $\frac{1}{12}$  of copper. The best Silver plate is formed by uniting a plate of copper to the surface of a thin plate of Silver, and then extending the mass by passing it between steel rollers,

after which it is ready to be worked up into various ornamental and useful forms. Inferior plate is manufactured by applying an amalgam of Silver to the surface of the copper, after some adhesion is effected; the mercury is driven off by heat, and the Silver undergoes the operation of the burnisher. The brass dials of clocks, thermometer and barometer scales, &c. are silvered by rubbing upon them a mixture of whiting, pearlash, and chloride of Silver. A similar composition is often sold in small balls in the streets of London for beautifying old brass candlesticks. According to Stodart and Faraday, (*Quarterly Jour.* vol. ix.) an alloy of one part of Silver with 500 of steel is admirably adapted for the manufacture of cutting instruments. *Indelible marking ink* is made by dissolving ten grains of lunar caustic in half an ounce of gum-water; with this ink, the linen is to be marked from a common pen, but to prevent the corrosive quality of the salt it is necessary to moisten the linen with a weak solution of pearlash, which is suffered to dry before the ink is applied. It is a singular fact that if, instead of potash, soda be the alkali employed, the ink runs.

The *Arvor Diana*, a beautiful experiment of the Alchemists, is formed by putting into a flask six drachms of a saturated solution of nitrate of Silver, and four drachms of a saturated solution of nitrate of mercury, diluted with five ounces of distilled water; in this solution place a small lump of amalgam, consisting of seven parts of mercury with one of Silver. The flask is to remain perfectly quiet, and in a few hours a beautiful opalescent precipitate is produced.

Two very violent fulminating compounds of Silver are known to Chemists. The first was discovered by Berthollet, (*An. de Chim.* vol. i.) and is thus formed. Precipitate a solution of nitrate of Silver by lime-water. Wash the brown oxide thus produced in the open air, and let it be kept dry in a well-closed phial. To prepare the fulminating compound, put ten or twelve grains of this oxide into half an ounce of ammonia perfectly caustic, and moderately dilute. The oxide blackens, and more or less is dissolved. Pour the clear solution into a shallow vessel, and expose it to the action of the air. In ten or twelve hours, the surface becomes covered by a crystalline pellicle, which is the fulminating Silver. This formidable substance is to be removed while still wet, in lumps not exceeding two grains, to bits of blotting-paper, and suffered to dry. Even when wet, it will sometimes explode by a touch, and when dry the touch of a feather, or a bristle, will ignite it; the black powder which remains in the solution appears to possess the same properties; and so violent and uncertain is the action of this substance, that it is one of the last experiments we should advise a beginner to undertake.

The other fulminating Silver, though of great power, may be procured with more safety. The process for its formation is described in Art. (880.) See also *FULMINATING POWDERS*, in our *Miscellaneous Division*.

#### References to § 1.

(a.) *An. de Ch.* vol. lxxviii. (b.) Margraaf, *Opusc.* vol. i. and Faraday, *R. I. Jour.* vol. viii.; Lewis, *Com. Phil. Techn.*; Proust, *Nich. Jour.* vol. xv.; Thomson, *An. Phil.* vol. iv.; Faraday, *Quarterly Jour.* vol. iv.; Proust, *Jour. de Phys.* vol. xlix.; Rose, *Gehl. Jour.* vol. vi.; Marcet, *Nich. Jour.* vol. xx.; J. Davy, *Phil. Trans.* 1812; Coulomb, *An. de Ch.* vol. xliii.; Thomson, *Nich. Jour.* vol. xiv.; Fulhames, *Essay on Com-*

Chemistry. *lustion*; Brugnatelli, *An. de Ch.* vol. xxvii.; Gay Lussac, *An. de Ch.* vol. lxxviii.; Vauquelin, *An. de Ch.* vol. lxxxix.

Sect. II.—Palladium.

(917.) A. Palladium was obtained by Dr. Wollaston in 1803, from crude platinum, with which it exists as a native alloy, and also in separate grains, having a radiated structure.

(918.) B. The most simple process for obtaining it is by the addition of prussiate of mercury to a solution of crude platinum, one thousand parts of crude platinum containing seven of Palladium; a flocculent, yellowish-white precipitate of prussiate of Palladium is formed, which is easily reduced by heat to the metallic state.

(919.) C. This Metal is nearly white, and has much the appearance of platinum. It is harder than wrought iron. Its Specific Gravity has been stated from 11.3 to about 12.14. It is malleable, and not very elastic. By exposure to heat and air, it undergoes no change. Its fusing point is somewhat below that of platinum. When strongly heated, its surface receives a blue tarnish by which it may be distinguished from platinum.

(920.) D. The only known oxide was formed by Berzelius, who heated the filings of the Metal with potash and a little nitre. Its colour was chestnut-brown.

(921.) E. The chloride of this Metal has not been examined.

(922.) F. G. Unknown.

(923.) H. Sulphur unites with Palladium.

(924.) I. Palladium has been alloyed with several other Metals.

(925.) K. Sulphuric Acid does not act freely on this Metal; but when boiled upon it, some little is taken up, and a blue solution formed. Nitric Acid has rather more power, and forms a beautiful, red solution. Hydrochloric Acid, by aid of a boiling heat, produces a fine red solution. But nitro-muriatic Acid is the proper solvent of Palladium.

This Metal unites also with potassa and soda by fusion. Ammonia seems also capable of dissolving a small portion of the Metal.

(926.) L. Solutions of Palladium have usually a red colour. Ferro-hydrocyanate of potassa gives an olive-coloured precipitate. Hydro-sulphuret of potassa a dark-brown one. The alkalis an orange precipitate. By mercury and sulphate of iron, the Metal is precipitated in the metallic state. Hydrochlorate of tin changes a very dilute solution to a fine emerald-green colour, but in a concentrated solution produces a brown precipitate. Hydrochlorate of ammonia produces no precipitation; thus distinguishing Palladium from platinum.

(927.) M. The scarcity of Palladium has prevented its general application to any purpose in the Arts; except that Mr. Troughton graduated the celebrated mural circle at Greenwich upon an alloy of gold and Palladium, furnished by Dr. Wollaston, but he does not consider that gold alone would be inferior.

References to § 2.

Chenevix, *Phil. Trans.* 1803; Wollaston, *Phil. Trans.* 1804 and 1805; Vauquelin, *An. de Ch.* vol. lxxviii.; Berzelius, *An. Phil.* vol. iii. and *An. de Ch. et de Ph.* vol. x.

Sect. III.—Rhodium.

Part II.

(928.) A. Rhodium was discovered in 1803, by Dr. Wollaston, with palladium in crude platinum, which contains about four parts in one thousand of this Metal.

(929.) B. Dr. Wollaston's process for obtaining it is this. Expel the mercury from crude platinum by a red heat; digest upon the Metal a small quantity of nitro-muriatic Acid to remove the gold. Dissolve in dilute nitro-muriatic Acid, digesting it in a sand heat in such a manner that a portion may remain undissolved, and the Acid be perfectly saturated. The greater part of the platinum may be precipitated by a hot solution of hydrochlorate of ammonia. By immersion of a plate of zinc the iron remains in solution, and a black powder falls, containing platinum, palladium, Rhodium, copper, and lead. The last two Metals may be removed by dilute nitric Acid. After again forming a solution by nitro-muriatic Acid, a small quantity of hydrochlorate of soda is added, and the whole evaporated to dryness; alcohol then removes every thing, leaving the hydrochlorate of Rhodium undissolved. By solution in water, and again immersing a plate of zinc, a black powder is precipitated, which, after heating with borax, assumes the metallic appearance, but does not enter into fusion.

(930.) C. Iridium excepted, this is the most infusible of Metals. Dr. Wollaston was unable to obtain from the grains a compact, metallic button, but Dr. Clarke produced, by the heat of the Gas-blowpipe, a small and malleable bead of this very refractory substance. Its colour is white, and in hardness it rather exceeds iron. Its Specific Gravity is 11. or perhaps rather less.

(931.) D. According to Berzelius, there are three oxides of this Metal: a black one formed by exposing the Metal to heat with access of air; another, formed by heating powdered Rhodium with potassa and a little nitre, is of a brown colour; and a third, which is obtained by precipitation from the soda-muriate by potash, exists in the state of a hydrate. By heat, the water and a part of the oxygen is driven off, and an inferior oxide remains.

(932.) E. Of the action of chlorine we know nothing; but as a Salt may be formed by the hydrochloric Acid, it is probable that a chloride may exist.

(933.) F. G. Unascertained.

(934.) H. With sulphur, Rhodium very readily unites, but with other substances of this class its properties are unknown.

(935.) I. Dr. Wollaston found that this Metal combined with all Metals that he tried except mercury.

(936.) K. Rhodium resists the action of all Acids; but Dr. Wollaston found the highest oxide soluble in all the Acids that he tried. He describes a nitrate and a sulphate, obtained by an indirect process.

Oxide of Rhodium readily forms double Salts with hydrochloric Acid and alkalis; which Salts are insoluble in alcohol.

(937.) L. Solutions and Salts of Rhodium have a beautiful red colour, and from this property the Metal derives its name (*ρῶδιος*, rosy.) No precipitate is produced by prussiate of potassa, nor by the hydrosulphates. The alkaline carbonates give no precipitate, but the pure alkalis give a yellow one soluble in excess of the alkali.

(938.) M. In the Arts, Rhodium would probably,

**Chemistry.** from its hardness, prove eminently useful, if it were more plentiful. Messrs. Stodart and Faraday speak highly of its properties, in their experiments on metallic alloys.

#### References to § 3.

Wollaston, *Phil. Trans.* 1804; Descottls, *Jour. de Ph.* vol. lxi.; Berzelius, *An. Phil.* vol. iii.; Vauquelin, *An. de Ch.* vol. lxxviii.

#### Sect. IV.—Platinum.

(939.) A. Platinum is first known to have been seen by Mr. Wood, assay-master in Jamaica, in 1741. From him, Dr. Brownrigg received a specimen which was presented to the Royal Society in 1750. In 1748 it was seen by Ulloa, a Spanish Mathematician, who accompanied the French Academicians, in 1735, to Peru, for the purpose of measuring a degree of the meridian. Experiments on it were published by Wood, in 1750, (a.) and by Lewis, in 1754. (b.) Other dissertations on it may be found from the references to this section. (c.) The first Platinum known was from Choco and Santa Fé, in South America. Vauquelin detected it among some silver-ores from Estramadura; it has subsequently been brought from St. Domingo, and from the gold-mines of Brazil. Still more recently it has been found in the Province of Antioquia, in North America; and abundantly in the Ural mountains. (d.) Its name is derived from the Spanish as a diminutive from *plata*, silver; hence *platina*, and its Latin *Platinum*.

This substance is found in the metallic state either nearly pure, or alloyed with iron, copper, lead, gold, silver, palladium, rhodium, iridium, and osmium.

(940.) B. The grains of crude Platinum are to be dissolved in concentrated nitro-muriatic Acid, with as little heat as possible. Decant off the solution from a black precipitate which remains. A solution of sal ammoniac dropped into the solution, throws down a yellow precipitate; which is to be washed, dried, and gradually raised to a red heat in a porcelain-crucible. Pure Platinum remains in a pulverulent state, and may, by heat and mechanical compression, be reduced to an ingot. (d.)

(941.) C. Pure Platinum is less white than silver; and has inferior lustre. It is the heaviest Metal known, having a Specific Gravity = 21, or 22. It is soft, malleable, ductile, and of very difficult fusibility; and a comparatively slow conductor of heat. Has the property of welding.

(942.) D. Platinum is not oxidized by exposure to heat and air. Its oxides are obtained by precipitation from saline solutions. Three oxides are described by Chemists, but the first is not quite well ascertained.

(943.) E. Nitro-muriatic Acid is the best solvent of Platinum; but it is also acted upon by pure Chlorine. The point is not fully ascertained, but it seems probable that there are three chlorides of Platinum.

(944.) F. Unknown.

(945.) G. Unexamined.

(946.) H. Sulphuret of Platinum has been formed, but it seems to be a compound not possessed of great stability. (e.) The phosphuret is a bluish-grey powder not fusible. The seleniuret is described by Berzelius.

(947.) I. On the whole, Platinum may be considered

as well disposed to form alloys with the other Metals; and, in some instances, the combination is effected with great violence.

(948.) K. Platinum is not acted upon by any Acid except the nitro-muriatic; but its oxides form numerous Salts with other Acids by indirect processes. The alkalis, also, aided by heat, have some action upon it; hence a caution arises with regard to the use of Platinum-crucibles in analysis.

(949.) L. Solutions of the Salts of Platinum have a yellowish or reddish-brown colour. They are not precipitated by infusion of galls, or by prussiate of potassa. Pure ammonia, or potassa, throw down small orange-coloured crystals. Hydrosulphuric Acid throws down a black, pulverulent precipitate.

(950.) M. The very difficult fusibility of Platinum renders it a valuable Metal, in forming apparatus for many purposes of Chemical research. Being harder and less fusible than gold it is now used for the touch-holes of guns; perhaps, also, it unites better with the iron of the barrel.

#### References to § 4.

(a.) *Phil. Trans.* vol. xlv. (b.) *Phil. Trans.* vol. xlviii. and l. (c.) Lewis, *Com Phil. Techn.* p. 443; Margraaf, *Opusc.* vol. ii. p. 226; Macquer and Beaume, *Mém. Par. Acad.* 1758, p. 119; Buffon, &c. *Jour. de Ph.* vol. iii. p. 234; Bergman, *Opusc.* vol. ii. p. 166; Lavoisier, *An. de Ch.* vol. v. p. 137; Moussin Poushkin, *An. de Ch.* vol. xxiv. p. 205; Morveau, *An. de Ch.* vol. xxv. p. 3; Berzelius, *An. de Ch.* vol. lxxxiii.; E. Davy, *Phil. Mag.* vol. xl. pp. 27, 209, 263, 350. (d.) Wollaston, *Phil. Trans.* 1827. (e.) Vauquelin, *An. de Ch. et de Ph.* vol. v. p. 263.

#### Sect. V.—Gold.

(951.) A. This beautiful and valuable Metal has been known from the earliest times; a circumstance easily explained when we remember that it usually occurs in the native metallic state. From one other ore only is it obtained in any considerable quantity, in which it is combined with tellurium. Native Gold is found principally in filaments traversing primitive rocks, in the beds of rivers, in grains washed out from similar mountains, or in alluvial soils.

(952.) B. When the grains of Metal are sufficiently large to be visible, they are picked out and purified by fusion and cupellation. But when the grains are very minute, and mingled with sand, or it is necessary to pulverize the rocky matrix containing the Metal, it is usual to complete the process by amalgamation. The sand, or powder, is first washed with water in such a way as to allow the heavier particles of Gold to remain in the vessel, this auriferous sand is then agitated with mercury, by which the Gold is taken up and the silicious matter remains. The mercury is then distilled off from the Gold, and subsequent cupellation is employed to remove any impurity arising from the baser Metals. Should silver also be present, the assayer's operation of parting is resorted to to obtain absolute purity.

(953.) C. Various shades of yellow describe the colour of Gold; and it is singular that, without affecting any of its other properties, if a small quantity of borax be added to Gold in fusion, the colour becomes very pale, whilst nitre has the contrary property of rendering

**Chemistry.** It very high-coloured. It is capable of a high polish from the burnisher. Its Specific Gravity is about 19.3, being higher than any other Metal, platina excepted. It is the most ductile and malleable of metals. "It may be beaten out into leaves so thin, that one grain of Gold will cover  $56\frac{1}{2}$  square inches. These leaves are only 1-282000 of an inch thick. But the Gold leaf with which silver wire is covered, has only 1-12 of that thickness. An ounce of Gold upon silver wire is capable of being extended more than 1300 miles in length." (Thomson.)

Great as is the density of Gold, if one of these leaves be carefully spread between two plates of glass, it will be found to transmit the green rays of light; and it is singular that the same colour is developed on the surface of a mass of Gold in a state of fusion.

In tenacity, Gold is inferior to iron, copper, platinum, and silver. Its fusing point may roughly be stated at  $1800^{\circ}$  Fahrenheit. In all furnace heats it may be considered as absolutely fixed; but by the heat of Tschirnhaan's lens, the discharge of an Electrical battery, or the Gas blowpipe, it may be volatilized. The fumes raised by the first of these processes were seen by Macquer to gild a plate of silver placed five or six inches above it.

(954.) C. Exposed to atmospheric air, to oxygen, or to water, Gold undergoes no alteration, but aided by the heat of a powerful lens, or by an Electric discharge, its oxide may be formed though in very minute quantities. By the heat of the Voltaic pile, or the Gas-blowpipe, leaves or small wires of Gold undergo rapid combustion, and an oxide is produced. It is the general opinion of Chemists that there are at least two oxides of Gold. If a solution of Gold in nitro-muriatic Acid be evaporated just to dryness, and redissolved in water, and to this neutral solution caustic potash be added, and the whole exposed to heat, an abundant precipitate is produced. This is to be carefully washed with water, and dried, but without artificial heat. Thus is formed a reddish brown powder, the tritoxide of Gold; which by a very moderate heat again parts with its oxygen, and returns to the metallic state.

If instead of evaporating only to dryness the trit-hydrochlorate formed in the above experiment, the heat is continued as long as any Acid Gas is evolved, a straw-coloured mass remains insoluble in cold water, which is a prot-hydrochlorate of Gold; and from this a green-coloured protoxide may be separated by digestion in caustic potassa. This combination does not, however, possess great permanency, for one-third of it passes to the state of tritoxide at the expense of the other two-thirds, which return to the metallic state. Clearly, then, the tritoxide contains thrice as much oxygen as the protoxide, and Berzelius has strong ground for his suspicion that an intermediate oxide exists.

(955.) E. When Gold in a state of minute division is heated in chlorine, a yellow chloride is formed, which by the addition of water passes into a hydrochlorate, as is usual in such cases.

(956.) F. Unknown.

(957.) G. Hydriodate of potash produces in a solution of muriate of Gold, a brownish-yellow precipitate, insoluble in cold water, and decomposable by heat.

(958.) H. Gold does not unite with azote, hydrogen, carbon, boron, or silicon. Pelletier formed the phosphuret by dropping small pieces of phosphorus into Gold in fusion, and Oberkampf by precipitating hydrochlorate of Gold, by water impregnated with phos-

phuretted hydrogen Gas. Its affinity for sulphur is very slight, but when an alkaline hydrosulphuret is dropped into a solution of Gold, the black metallic sulphuret is precipitated.

(959.) I. As far as hitherto known, Gold appears to unite with every Metal, undergoing such change of properties, as to present a wide field of research. Most ably and laboriously has this inquiry been prosecuted by Mr. Hatchett. (b.) All Metals, except silver, copper, and platinum, seem materially to injure its ductility and colour. Lead, bismuth, and antimony, in very small proportions, render it brittle.

(960.) K. Solution of chlorine and the nitro-muriatic Acid are the only decided solvents of Gold; two parts of muriatic to one of nitric Acid form the usual proportions, but three of the former to one of the latter is considered still more effective.

Concentrated nitric Acid dissolves the oxide, and thus a pernitrate is obtained; but the combination is so slight, that either heat or dilution again throws down the metallic oxide.

In a similar manner the tritosulphate is obtained. The hydrochlorate has been before described. Further researches on the Salts of Gold are wanted.

Pelletier states that oxide of Gold is soluble in hydrate of potassa; and in this combination he considers that it acts the part of an Acid. It would also appear that in the process given above for obtaining the tritoxide of Gold, a portion of the Metal remains in solution in the state of a double hydrochlorate of potassa and Gold of high solubility.

(961.) If to a solution of hydrochlorate of Gold diluted with thrice its weight of water, ammonia be added so long as there is any precipitate, but without adding excess, the reddish yellow precipitate, when washed in water and dried by exposure to air, is Fulminating Gold, a preparation long known to Chemists. By the slightest heat, by percussion, or by friction, it explodes with violence. The temperature necessary to produce this effect has been estimated by Bergman between  $120^{\circ}$  and  $300^{\circ}$ . The powder appears to be a true ammoniuret of Gold; and on its detonation, according to Bergman, the following changes take place. The oxygen of the oxide attracts the hydrogen of the ammonia, and watery vapour is produced; the nitrogen also is liberated; and to the elasticity of these two Gaseous bodies, increased by the temperature, the violent effects are attributable. See FULMINATING POWDERS in our *Miscellaneous Division*.

(962.) L. In the solutions of the Salts of Gold, prussiate of potassa produces a yellowish-white precipitate. Infusion of galls gives to the solution a greenish hue, and precipitates the Gold in the metallic state. Hydrochlorate of tin, or a plate of metallic tin, produces a purple precipitate. Proto-sulphate of iron throws down metallic Gold, and from the powder thus produced, the most pure metallic Gold may be obtained. The rationale of this precipitation is simple and beautiful; the protoxide of iron has a strong affinity for more oxygen, and the Gold having only a very weak one, the former is oxidated at the expense of the latter, which being no longer soluble, falls down in the metallic state. Copper, iron, and zinc also precipitate Gold in the metallic state, and several other Metals in the state of a purple oxide.

(963.) M. Perhaps the most important among the uses of Gold is that of coinage: its great ductility fits it

**Chemistry.** for receiving a sharp and beautiful impression from the die, while its scarcity gives to it a convenient value with reference to the other Metals of coinage. Pure Gold is not so well adapted to this purpose as those alloys which possess sufficient hardness to resist the wear to which all coin is subject. The standard or sterling Gold of England consists of twenty-two parts (carats) of pure Gold to two parts of alloy. The alloy consists of silver or copper, or both, according to the colour which is required; the latter Metal having a great tendency to lighten the colour of Gold. It would appear from Mr. Hatchett's experiments that the alloy used in our Gold coinage is the best possible for the purpose, as it resisted ordinary friction better than any other tried. The stamped Gold for watch-cases, &c. is of eighteen carats, for it contains one-fourth alloy; but compounds exist under the name of *Jeweller's Gold*, of every possible degree of deterioration.

One species of gilding upon Metal is performed by uniting Gold to the Metal at a gentle heat, and by the friction and pressure of the burnisher, but *atherial gilding*, as it is called, is performed upon steel, by mixing a saturated solution of muriate of Gold with three times its weight of sulphuric ether; ether dissolves the oxide of Gold, and the Acid, or a great part of it, subsides. If polished steel be then dipped in the atherial solution, and immediately immersed in water, it is found to have received a delicate coating of metallic Gold on its surface. (Stodart.) For colouring glass and porcelain, the beautiful, purple precipitate produced by adding protomuriate of tin to a solution of Gold, has long been known under the name of the *Purple powder of Cassius*, the real nature of which still remains rather uncertain among Chemists.

Greatly as the Alchemists boasted of its virtues, Gold had fallen entirely into disuse as a medicine, until very lately; but it now seems to be likely again to have a place in the *Materia Medica*.

#### References to § 5.

(a) Lewis, *Commercium, Phil. Techn.* fol. 1763; Præust, *Jour. de Phys.* vol. lxi. or *Nich. Jour.* vol. xiv.; Vauquelin, *An. de Ch.* vol. lxxvii.; Oberkampf, *An. de Ch.* vol. lxxx.; Berzelius, *An. de Ch.* vol. lxxxiii.; Hatchett, *Phil. Trans.* 1803; Hellot, *Mém. Acad. Par.* 1735; Tillet, *Mém. de l'Acad. Par.* 1735; Fournier, *An. de Ch. et de Ph.* vol. ii.; Bergman, *Opusc.*; Stodart on Gilding by Ether, *Nich. Jour.* vol. xi. (b) *Phil. Trans.* 1803.

#### Sect. VI.—Iridium.

(961.) A. Iridium received its name from its discoverer, Professor Tennant, on account of the varying colours of its solutions. Together with osmium, it forms the black powder, remaining after the digestion and solution of crude platinum in nitro-muriatic Acid. Descotils made the same discovery, and Fourcroy and Vauquelin published a series of experiments on these two bodies. Dr. Wollaston perceived that the flat, foliated, white grains in crude platinum were in fact the native alloy of the two Metals.

(965.) B. The black powder above mentioned is to be mixed with an equal weight of potash in a silver-crucible, and continued in a red heat for some time. From

this, water procures an orange-coloured solution. The remaining, undissolved powder is to be digested in hydrochloric Acid, and then again subjected to the action of potash as before; these alternate actions being repeated till all is dissolved. Thus an orange-coloured, alkaline solution is obtained, holding the oxide of osmium, combined with potash, and a deep-red acid solution of oxide of Iridium. By evaporating this latter solution to dryness, and again dissolving in water and evaporating, octahedral crystals of hydrochlorate of Iridium are obtained. From a solution of these, a plate of any Metal, except gold and platinum, will throw down Iridium as a black, metallic powder.

(966.) C. This powder, after the purification of a strong heat, is rather whiter than platinum, but can scarcely be said to have been fused, although Mr. Children's powerful Galvanic battery produced an imperfect agglutination of the particles, and the same has since been effected by Dr. Clarke with the Gas-blowpipe. The experiments of Vauquelin render it probable that, after a perfect fusion, this Metal may be slightly ductile; its Specific Gravity is certainly above 18.6.

(967.) D. The affinity of Iridium for oxygen is extremely slight, but it is probable that it forms more than one oxide. By the addition of an alkali to any acid solution of this Metal, one portion of the oxide is precipitated, and another retained in solution. Descotils procured also a blue, volatilized oxide by exposing the Metal to a strong heat.

(968.) E. F. G. Unknown.

(969.) H. Iridium may be indirectly combined with sulphur. Its action with phosphorus and selenium is not known, and with the other substances of this class its combination is not very probable.

(970.) I. Tennant alloyed it with lead, copper, silver, and gold, but could form no alloy with arsenic. Vauquelin combined it with tin; and like rhodium, it appears to increase the hardness of the Metals with which it is combined.

(971.) K. No single Acid is capable of dissolving Iridium; even the nitro-muriatic is with difficulty made to take up one-three-hundredth of its weight of the Metal.

The sulphate and hydrochlorate of this Metal give green or blue solutions according to their state of dilution; the nitrate, when concentrated, has a red colour. Double Salts of the hydrochloric Acid with the alkalis and oxide of Iridium exist, and are of a deep-purple colour.

(972.) L. From solutions of this Metal almost all Metals produce a precipitate of reduced Iridium, owing to its weak affinity for oxygen. Tincture of galls produces after some time a red precipitate; but according to Tennant the solution of the crystallized hydrochlorate is only rendered colourless by infusion of galls. Prussiate of potassa, hydrochlorate of tin, and carbonate of potassa, without any precipitation being produced. Hydrosulphurets destroy the colour of the solution, but by aid of heat produce a black precipitate.

(973.) M. None.

#### References to § 6.

Tennant, *Phil. Trans.* 1804; Descotils, *An. de Ch.* vol. xlviii.; Fourcroy and Vauquelin, *An. de Ch.* vol. xlix. and vol. l.; Vauquelin, *An. de Ch.* vol. lxxxix.

## PART III.

## CHEMISTRY OF ORGANIZED BODIES.

Chemistry.

(974.) We have now arrived at a difficult but most interesting and important branch of Chemical Science. There are but two methods for producing a really useful review of the state of knowledge on the subjects to which this Part refers. The one to give a detailed and systematic account of all the researches which have been made on the various Organic substances; and the other merely to recite their names, giving little more than a complete series of references to the original Memoirs for the benefit of those who may wish to enter these fertile fields of discovery. A middle course would offer little real utility. From the former we are prohibited by the space which such a Treatise would occupy in this Work: and we therefore adopt the latter.

By Organic Chemistry we are to understand the examination of the properties, the proximate and ultimate analyses of all substances, immediately seen in, or ultimately to be traced to, the vegetable or animal kingdoms; products obtained from, or educts existing in, organized bodies. Numerous as are the substances referable to this class they are formed from a very few ultimate elements; and can, therefore, differ only in the proportions of these elements, or in the mode of their combination. Oxygen, hydrogen, carbon, and nitrogen are the principal ultimate elements so employed by Nature. With these are united, but in far smaller quantities, some earths and metals, with phosphorus and sulphur. Organic substances, therefore, may generally be resolved into the same ultimate elements; though for the most part in dissimilar proportions, they readily undergo decomposition, a red-heat is at all times sufficient for this purpose, and in numerous cases the decomposition is rapid and spontaneous even at ordinary temperatures. By slight causes the affinities and constitutions of these substances are overturned, and new products result; but in most cases it is impossible to reproduce the original substance by a direct union of its constituent ultimate elements.

The proximate analysis of an Organic substance separates it into its proximate elements; that is, into various substances, acid, alkaline, or otherwise, each of which, though itself a compound body, possesses distinct properties, and a definite constitution of two or more ultimate elements. By the ultimate analysis each of these proximate elements is resolved into its ultimate elementary constituents. If, for instance, a few leaves of wood-sorrel were at once submitted to ultimate analysis, we should obtain carbon, oxygen, hydrogen, potash, and one or two other substances of minor importance, and should learn but little of the constitution of the plant or its juices: but if we proceed more systematically, we shall obtain in the proximate elements an Acid called the oxalic; an alkali, potassa, and a small quantity of residuary matter, producing the colour and substance of a plant; and we learn, that a true Chemical Salt, formed by the Acid and the alkali, constitute the peculiarities of the juices of the plant. We then may proceed to the ultimate analysis of both the potassa and the oxalic Acid, resolving the former into oxygen

and a metal; the latter into oxygen, hydrogen, and carbon.

Part III.

The first efforts at Organic analysis consisted simply of destructive distillation, by which the substance might, indeed, be resolved into its Gaseous elements. Those, however, form new combinations among themselves, and this method is therefore very properly abandoned, except for special purposes.

MM. Gay Lussac and Thenard proposed the application of some substance which should readily afford oxygen when heated with the substance to be analyzed. For this purpose they first employed chlorate of potassa, and subsequently the black oxide of copper. This oxide will, if alone, bear a white-heat without parting with its oxygen; though it readily does so at a much lower temperature if any combustible be present. Hence, if three or four grains of any Organic substance containing hydrogen and carbon be mixed with the oxide of copper in a green glass or metal tube, and then exposed to heat, so disposed as to collect the gaseous products over mercury, carbonic Acid Gas and water will be obtained. The former indicates the quantity of carbon, the latter the quantity of hydrogen. The loss of weight sustained by the oxide should in this case agree with the oxygen employed in producing the water and the carbonic Acid. But if oxygen also had been present in the substance analyzed, this would be indicated by a proportion of oxygenized products greater than that due to the mere loss on the oxide of copper. If nitrogen forms a constituent of the substance analyzed, it will pass over in the Gaseous state, and may be separated from the carbonic Acid by removing the latter by potassa. Such is the outline of this process, but for the numerous minutiae to be observed, consult the references. (a.) Very recently, Dr. Prout has devised a most elegant apparatus and method, which may be seen in the *Philosophical Transactions*. (b.) The presence of water in the substance to be examined is to be most carefully avoided; and this is best effected by drying it in an exhausted receiver, at some moderate elevation of temperature, and in presence of some highly absorbent substance, such as sulphuric Acid. A convenient apparatus for this purpose has been devised by Dr. Prout. (c.) We owe also to Mr. Cooper (d.) and to Dr. Ure some useful suggestions and apparatus in this branch of analysis.

It has been found that some proximate elements, having very distinctive Chemical properties, present on ultimate analysis the very same elements, and in the same proportions. Hence it is inferred that such differences as constitute distinct substances, may arise solely from different modes of combination existing among the ultimate elementary atoms. Of this opinion is Gay Lussac, who considers alcohol, for instance, as consisting of a compound of olefiant Gas with water, whilst Berzelius, on the other hand, considers it only a universal compound of atoms of hydrogen, carbon, and oxygen.



## CHAPTER I.

## CHEMISTRY OF VEGETABLE BODIES.

(975.) We shall now, for the most part, follow M. Thenard in giving a very brief abstract of Vegetable Chemistry. The following laws he considers to be general, as far as researches at present extend.

1. That when a Vegetable substance does not contain nitrogen, and that when the quantity of its oxygen is to the quantity of its hydrogen in a greater ratio than is due to the constitution of water, the substance is acid, whatever be the quantity of carbon entering into its composition.

2. That when these properties are reversed, the substance *may* still be acid, but that in general it is oily, resinous, alcoholic, or ethereal.

3. That when the oxygen and hydrogen are in just ratio for the formation of water, the substance is analogous to sugar, gum, woody fibre, &c.

4. That when any Vegetable substance contains much hydrogen, it contains at the same time much carbon, and the converse.

5. That many Vegetable substances may be represented, as to their composition, by a certain number of volumes of vapour of carbon, of hydrogen Gas, and of oxygen Gas; or by a certain number of volumes of some of those binary compounds which may be produced between hydrogen, oxygen, and carbon.

6. That no Vegetable substance contains at the same time oxygen enough to transform both its hydrogen and carbon into water and carbonic Acid.

Accordant with these views, M. Thenard treats of Vegetable substances under seven different heads, a division which we can only in part adopt.

CLASS I. Vegetable proximate elements in which the oxygen is in excess with regard to the hydrogen as to the formation of water.

Division 1. Acids.

Division 2. Alkalis.

CLASS II. Vegetable proximate elements in which the oxygen is in defect with regard to hydrogen as to the formation of water. Oils, bitumens, alcohol, ethers, &c.

CLASS III. Vegetable proximate elements in which the oxygen and hydrogen are in just proportion for the formation of water. Sugar, honey, gums, &c.

CLASS IV. Vegetable colouring principles.

CLASS V. Vegetable proximate elements not noticed in any of the preceding Classes.

(976.) As a general outline of the properties of these substances, it may be well to bear in mind, that all are either solid or liquid at all ordinary temperatures. Many are volatile *per se*, as for example, alcohol, ether, essential oils, others are readily vaporized in different Gases, such are camphor, benzoic, and oxalic Acid. Others are fixed at all temperatures which do not produce their decomposition.

When submitted to distillation, the former undergo no constitutional change, the second sort are partly volatilized and partly decomposed, and the last are entirely decomposed. From the decomposition of those which do not contain nitrogen, there result water, carbonic Acid, acetic Acid, gaseous oxide of carbon, oil,

carbon, and carburetted hydrogen. But those which contain nitrogen, afford in addition ammonia, hydrocyanic Acid, and nitrogen Gas. Part III

By the aid of air and moisture many of these substances undergo spontaneous decomposition. For more complete details of the action of the other simple and compound elements we must refer to the Work of M. Thenard. (c.)

(a.) Gay Lussac and Thenard, *Rech.* vol. ii.; Prout, *An. Phil.* vol. iv. p. 270; Thenard on Anal. Children's Translation; Prout's *Apparatus*, Henry's *Elements*, vol. ii. p. 162; Bischoff, *An. Phil.* N. S. vol. viii. p. 308. (b.) Prout, *Phil. Trans.* 1827, p. 129. (c.) *An. Phil.* vol. iv. p. 272. (d.) *An. Phil.* N. S. vol. vii. p. 170. (e.) *Traité*, vol. iii. p. 576.

## CLASS I. DIVISION I.

*Vegetable Acids.*

(977.) With the greater part of these substances the salifiable bases unite to form Salts. All reddened Vegetable blues, and all consist of oxygen, hydrogen, and carbon. M. Thenard enumerates thirty-four which have been mentioned by Chemists, but some are now proved to be identical substances.

*Acids that are both natural and artificial.*

(978.) *Acetic.* This Acid has been long known; it is most abundantly obtained by the acetous fermentation, or by the destructive distillation of Vegetable bodies, and it is found among the juices of some plants. The impure acetous Acid, now obtained from the distillation of wood, is called pyroligneous Acid, and by subsequent purification becomes a limpid vinegar, or a much stronger Acid according to circumstances. The strongest acetic Acid is obtained by distillation from the acetates, those especially of potassa or copper. Thomson has shown that the only correct estimate of acetic Acid is to be found in its neutralizing power, and that the Specific Gravity cannot be depended upon. This Acid forms numerous and important Salts.

See Mollérat, *An. de Ch.* vol. lxviii.; Colin, *An. de Ch. et Ph.* vol. xii.; Darracq, *An. de Ch.* vol. xli.; Che-  
nevix, *An. de Ch.* vol. lxi.; Berzelius, *An. de Ch. et Ph.* vol. xxvi.; Phillips, *An. Phil.* N. S. vol. i. ii. iv.; Berzelius, *An. Phil.* N. S. vol. viii.

(979.) *Malic Acid* was discovered by Scheele in 1785. It exists in the juice of the apple, and hence its name. Also in the juices of gooseberries, currants, and oranges. In the houseleek, where it is combined with lime. Mr. Donovan discovered in the juice of the fruit of the *Sorbus aucuparia*, an Acid which, not agreeing with the described characters of the malic, he called the sorbic. It seems now proved that the Acids are the same, but that Mr. Donovan's description was accurate, and those previous to his not so, from impurities present in the malic Acids heretofore examined. This Acid forms Salts which are soluble in water and some highly so.

See Donovan, *Phil. Trans.* 1815; Braconnot, *An. de Ch. et Ph.* vol. vi. viii.

(980.) *Oxalic Acid.* This Acid was first recognised by Bergman. It is found in the *Oxalis acetosella*, (wood-sorrel,) in the *Rumex acetosa*, (common sorrel,) and in several lichens. It may be formed abundantly by the action of nitric Acid on sugar. Oxalic

chemistry. Acid seems to have this peculiarity that it contains no hydrogen. It is a most rapid and fatal poison.

See Berzelius, *An. de Ch.* vol. xciv.; Döbereiner, *An. de Ch. et Ph.* vol. xix.; Gay Lussac and Thenard, *Rech.*; Thomson, *First Principles*, vol. ii.; Wollaston, *Phil. Trans.* 1818.

#### *Acids produced by Nature only.*

(981.) *Benzoic Acid.* A substance found in some balsams; in vanilla, castor, in some plants, and in the urine of some herbivorous animals. It is obtained in white, crystalline filaments by sublimation. A few Salts formed by this Acid have been described.

See Fourcroy, *An. de Ch.* vol. lxix.; Berzelius, *An. de Ch.* vol. xciv.

(982.) *Citric Acid.* Scheele first submitted the juice of the lemon to Chemical examination and proved it to contain a distinct Acid. It exists also in small proportion in some other fruits. This Acid crystallizes readily.

Consult Fourcroy, *Système*; Gay Lussac and Thenard, *Recherches*; Berzelius, *An. de Ch.* vol. xciv.

(983.) *Fungic Acid.* M. Braconnot has thus named an Acid found by him in the juice of some of the Fungi.

See *An. de Ch.* vol. lxxxvii. p. 237. 253.

(984.) *Gallic Acid.* This Acid was examined and described by Scheele in 1786. It is found in some astringent barks and in the gall-nut.

See Scheele, *Essays*; Braconnot, *An. de Ch. et Ph.* vol. ix.

(985.) *Ellagic Acid.* Such is the name formed by reversing the word Galle, and applied by M. Braconnot, in 1818, to an Acid first noticed by M. Chevreul in 1815; and supposed to exist in the gall-nut together with the gallic. This Acid is little known.

See *An. de Ch. et Ph.* vol. ix. p. 187.

(986.) *Iguanuric Acid.* This substance, so termed by MM. Pelletier and Caventou, was discovered by them in examining the active principles of the bean of St. Ignatius. (*Nux vomica*.) M. Thenard has doubts of the peculiar nature of this Acid.

See Pelletier, *An. de Ch. et Ph.* vol. x. p. 167.

(987.) *Quinic Acid.* This Acid is found in the Quina, or Cinchona bark, united with other Vegetable elements. It has a strong, acid flavour, free from all bitterness; does not easily crystallize; forms a class of Salts which have been little studied. See Vauquelin, *An. de Ch.* vol. lix. By English writers this Acid is sometimes spelt Kinic.

(988.) *Lactic Acid.* Such is the name given by M. John to an Acid which he obtained from Stick Lac. It is at present very little known. See Schweiggers, *Journ.*, vol. xv.; or *An. de Ch. et Ph.* vol. i. p. 445; Pearson, *Phil. Trans.* 1794.

(989.) *Meconic Acid.* This Acid was discovered by M. Sertürner, in his valuable researches into the constituent principles of opium. It derives its name from *μῆκων*, a poppy. See Sertürner, *An. de Ch. et Ph.* vol. v. p. 21; Robiquet, *An. de Ch. et Ph.* vol. v. p. 260.

(990.) *Mellitic Acid.* Klaproth discovered this Acid combined with alumina in a rare mineral then called Honey-stone from its colour. Consult *An. de Ch.* vol. xxxvi. p. 203, and vol. xlv. p. 232.

(991.) *Moric or Moroxalic Acid.* From the juice of the mulberry (*Morus alba*) M. Klaproth, in 1803, obtained this Acid. See *Dict. de Chimie de Klaproth* and Wolff, Thomson, *Nich. Jour.* vol. vii. p. 129.

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Part III.

(992.) *Pectic Acid.* This substance, admitted by M. Thenard into his *System*, was discovered by M. Payen first in the bark of the root of the plant producing Japan varnish. M. Braconnot has continued the inquiry, and found the same substance to exist in all Vegetables. The name is derived from *πηκτις*, a coagulum, from the gelatinous appearance which it always presents. See Payen, *Jour. de Pharmacie*, vol. x. p. 385; and *Jour. de Chim. Médicale*, vol. i. p. 539; Braconnot, *An. de Ch. et Ph.* vol. xxviii. p. 173, and vol. xxx. p. 96.

(993.) *Acid of the strychnos-pseudo-kina.* A substance very little known, but mentioned by Vauquelin. *Bulletin de la Société Philomatique, Mars, 1823.*

(994.) *Succinic Acid.* This Acid is obtained from amber by gentle distillation. It exists also in some sorts of turpentine, and a few of its Salts have been noticed. See Robiquet and Colin, *An. de Ch. et Ph.* vol. iv. p. 326; *An. Phil.* vol. xv. p. 388; Berzelius, *An. de Ch.* vol. xciv. p. 189.

(995.) *Sulpho-sinapic Acid.* MM. Henry and Garot separated this substance from the fixed oil of mustard. See *Jour. de Chimie Médicale*, No. X. and XI.

(996.) *Tartaric Acid.* After so many Acids, which as yet are scarcely known by name, we arrive at one that has been long noticed. Its presence was recognised in cream of tartar by Du Hamel, Margraaff, and Rouelle the younger; but Scheele first examined it in an uncombined form. Tartaric Acid seems to exist in the juices of several acidulous fruits, and is deposited in combination with lime and potassa in considerable quantity from new wines. The tartrates have excited considerable attention, as some are serviceable in Medicine: such are the tartrate of potassa and soda; (Rochelle Salts;) the bitartrate of potassa; (cream of tartar;) tartrate of antimony and potassa, (tartar emetic.) See Retzius, *Stock. Trans.* 1770; *An. de Ch.* vol. xlvii.; Thenard, *Syst.* vol. iii. p. 677.

#### *Acids produced solely by artificial Processes.*

(997.) *Camphoric Acid.* This substance is obtained from camphor by treating it with a large excess of nitric Acid. It was discovered in 1785 by M. Kosegarten. See *An. de Ch.* vol. xxiii. p. 153; vol. xxvii. p. 19; and vol. lxxxiv. p. 301.

(998.) *Mucic Acid.* This Acid was at one time called the sacclactic, because obtained by Scheele from sugar of milk in 1780. It is now formed by treating sugar of milk, gum, and some other substances with nitric Acid. See Scheele, *Memoirs*; Langier, *An. de Ch.* vol. lxxii. p. 81; Tromsdorff, *An. de Ch.* vol. lxxi. p. 79; Labillardière, *An. de Ch. et Ph.* vol. ix.; Berzelius, *An. de Ch.* vol. xciv.

(999.) *Nanceic Acid.* So named by its discoverer, M. Braconnot, from Nancy, the place of his residence. It appears to form spontaneously upon the change to acescence in certain Vegetable juices. *An. de Ch.* vol. lxxxvi. p. 84. The experiments of M. Vogel led M. Thenard to suspect this Acid to be identical with the lactic. *Jour. de Pharmacie*, vol. iii. p. 491.

(1000.) *Suberic Acid.* This Acid was discovered by M. Brugnatelli in 1787; it is formed by the action of nitric Acid on Cork. See Brugnatelli, *Crell's Annals*, 1787; Bouillon L'aprange, *An. de Ch.* vol. xxiii.; Chevreul, *An. de Ch.* vol. lxii.; Bussy, *Jour. de Pharm.* vol. viii. p. 107.

(1001.) *Pyr-Acids.* There is a class of Acids pro-

Chemistry. duced by the distillation of certain other Vegetable Acids. The names of those described are the Pyroci-  
tritic, Pyromalic, Pyromucic, and Pyro-tartaric. See  
Thenard, *Syst.* vol. iii. p. 706.

## DIVISION II.

### Vegetable Alkalies.

(1002.) The outline which we are about to give of the general properties of these substances is extracted from M. Thenard's *System*. The discovery of this class of bodies originated with M. Sertürner during his excellent analysis of opium, made in 1805. A subsequent Memoir, however, which he published in 1815, was the first to call the attention of Chemists effectually to the point.

The Vegetable Alkalies best known are morphia, strychnia, brucia, cinchonia, quinina, veratria, delphia, and emetia.

Picrotoxia, solania, caffeine, and atrophia seem to belong to the same class, but have been less studied.

Daphnia, hyoseyamia, daturia, aconitina, and cicutina have been announced, but are still less known.

All these Vegetable salifiable bases are solid, white, bitter or acrid, scentless, heavier than water, and change syrup of violet to green. Veratria, delphinia, and emetia can only be obtained in powder, but the rest are capable of crystallization. When decomposed by heat, they all give ammoniacal products among other Gases, in consequence of the nitrogen they contain. All are almost insoluble in water; alcohol being their true solvent. Sulphur does not combine with them. Chlorine and iodine, by aid of water, dissolve them. Their saturating power is feeble. Generally speaking, their sulphates, nitrates, and hydrochlorates are soluble. On the other hand, many neutral tartrates, oxalates, and gal-  
lates are insoluble. Excess of Acid always induces solubility. All alkalies, and even magnesia, disengage the Acids from these Vegetable bases; but in their turn these are capable of removing the Acids from most other oxides. In a neutral solution of one of these Vegetable Salts, infusion of galls forms, from the insolubility of the gallate, precipitates, which the Acids or alcohol redissolve.

These Vegetable Alkalies do not exist free in the Vegetables which produce them, but are there united with Acids; and as far as at present known, it is to the presence of these Salts that the active properties of the plants are due.

The general outline of the process by which they are separated is this: the Vegetable juices are boiled with magnesia and water. The precipitate obtained is dried and boiled in pure alcohol; thus a solution of the alkali is obtained, and from this the alcohol may be removed by careful evaporation.

All these alkalies contain oxygen, carbon, hydrogen, and nitrogen. The action of all on the animal economy is very active, and is greatly increased when they are in the state of Salts, from their more ready solubility.

(1003.) *Morphia*. This alkali, discovered by Sertürner, is obtained from opium, and bids fair, to form a most valuable addition to Medical Science. For the mode of its preparation see Robiquet, *An. de Ch. et Ph.* vol. v. p. 279; Hottot, *Jour. de Pharm.* vol. x. p. 475. For its medicinal application see Orfila, *Jour. de Chim. Médicale*, vol. i. p. 165, 221; Lassaigne, *An. de Ch. et*

*Ph.* vol. xxv. p. 102; Gaudner, *Med. and Phys. Jour.* Part III. vol. xl. p. 276; Bardsley, *Hospital Facts*, &c.

(1004.) *Cinchonia*. Dr. Duncan of Edinburgh first recognised this as a distinct Vegetable principle found in the Cinchona bark, and chiefly in the *Cinchonia Condaminea*. Its action seems to be much the same as that of Quinina, but being a rarer substance it is not in such general use. See Majendie, *Formulaire pour la Préparation et l'Emploi de plusieurs nouveaux Médicaments*.

(1005.) *Quinina*. This alkali was discovered by MM. Pelletier and Caventou in the yellow bark *Cinchonia cordifolia*. The sulphate is now very largely employed in Medicine, and its valuable properties are established beyond the reach of doubt. See Pelletier and Caventou, *An. de Ch. et Ph.* vol. xv.; Majendie, *ut supra*; Elliotson, *Medico-Chirur. Trans.* London, vol. vii. p. 534; Bardsley, *Hospital Facts*, p. 133.

(1006.) *Emetina*. This alkali, discovered by M. Pelletier, is found only in the Ipecacuanha root. It is the active emetic principle of that plant. See Pelletier, *Jour. de Pharm.* vol. iii.; *An. de Ch. et Ph.* vol. xxiv. p. 180; Majendie, *ut supra*.

(1007.) *Strychnia*. This was the first Vegetable alkali discovered by MM. Pelletier and Caventou; it exists in plants of the genus *Strychnos*, one of which is the *Nux vomica* bean. This also promises to form a valuable Medicine, especially in cases of paralysis. See Pelletier and Caventou, *An. de Ch. et Ph.* vol. x. p. 142; Bardsley, *Hospital Facts*, p. 1; Majendie, *ut supra*.

(1008.) *Brucea*. An alkali obtained from the false Angustura bark, (*Brucea anti-dysenterica*), existing also in the bean of St. Ignatius, or *Nux vomica*. See *An. de Ch. et Ph.* vol. xii. p. 113; Bardsley, *ut supra*, p. 59.

(1009.) *Veratria*. This alkali exists in the seed of the *Veratrum sebadilla*, the root of the white hellebore, *Veratrum album*, and in that of the *Colchicum autumnale*. See *An. de Ch. et Ph.* vol. xiv. p. 75; *Jour. de Ph.* 1821, p. 64; Bardsley, *op. cit.* p. 109.

(1010.) *Delphinia*. This substance has as yet been obtained only from the seeds of the *Delphinium staphisagria*. See Lassaigne and Feneulle, *An. de Ch. et Ph.* vol. xii. p. 358; *Jour. de Pharm.* vol. ix. p. 4.

(1011.) *Picrotoxia*. Boullay first recognised this alkali in the berry of the *Mentzpermum cocculcus*. Its name is derived from its bitter taste and poisonous properties. See *An. de Ch.* vol. lxxx.

(1012.) *Solania*. This substance, as yet little known, was found by M. Desfosses in the berries of the *Solanum nigrum*, and in the substance of the *Solanum dulcamara*. See Desfosses, *Jour. de Pharm.* vol. vi. p. 374, and vol. vii. p. 414; Payen and Chevallier, *Jour. de Ch. Méd.* vol. i. p. 517.

(1013.) *Atrophia*. M. Brandes discovered this alkali in the leaves of the *Atropa belladonna*. (Deadly Nightshade.) It seems to be a violent poison, similar in its operation to the decoction of the plant itself. See Brande, *An. Phil. N. S.* vol. i. p. 263; Runge, *An. de Ch. et Ph.* vol. xxvii. p. 32.

The remaining substances of this kind are at present little known; but we commit the subject to the attention of the Chemical reader with an assurance that in it he will find a wide field of interesting research; accompanied by a very reasonable expectation of arriving at results of the greatest importance to Medical Science.

Chemistry.

CLASS II.

*Vegetable Proximate Elements, in which the Oxygen is in defect with regard to the Hydrogen, as to the formation of water.*

These substances are in general oily, resinous, alcoholic, or ethereal; some among them possess acid properties. All are very rich in carbon, this substance sometimes amounting to four-fifths of their weight. They are in general fusible, and very combustible. Many may be volatilized by heat, unchanged; others are decomposed. Almost all are very soluble in spirits of wine, and insoluble, or very slightly so, in water.

(1014.) *Stearine and Elaiqe.* It appears from the researches of M. Chevreul that all fats and fixed oils contain two distinct principles to which he has applied these names. The former gives consistency, the latter, of a more liquid nature, produces fluidity. In the formation of soaps these principles are completely changed into three others, Margaric Acid, Oleic Acid, and Glycerine. See Chevreul *sur les Corps Gras*.

(1015.) *Fixed Oils.* These are for the most part liquid at our ordinary warmer temperatures. Yellow is the prevailing colour, and all are lighter than water. Of this class, olive oil, castor oil, nut oil, linseed oil, &c. will readily occur to the reader. For analyses of oils, see Gay Lussac and Thenard, *Recherches*; Saussure, *An. de Ch. et Ph.* vol. xiii. p. 351; Braconnot, *An. de Ch.* vol. xciii. p. 225. On the nature and formation of soaps, see Thenard, *Syst.* vol. iv. p. 70; D'Arcet, &c. *An. de Ch.* vol. xix. p. 253; Colin, *An. de Ch. et Ph.* vol. iii. p. 5; Marcel de Serres, *An. de Ch.* vol. lxxvi. p. 54; Chevreul *sur les Corps Gras*.

(1016.) *Essential Oils.* These oils, sometimes termed essences, contain the odoriferous properties of various plants, and hence they form, either alone, or as spirituous solutions, the basis of most perfumes. In many properties they differ from the fixed oils. They are acrid, caustic, very fluid, highly volatile, and readily combustible on the approach of burning bodies. Partially soluble in water, not capable of forming very intimate combinations with alkalis. Those most generally known are obtained from the lemon, bergamot orange, lavender, rosemary, aniseed, rose, jasmine, caraway seed, ambergris, and turpentine from the resin of the pine.

(1017.) *Resins.* These substances are generally solid, brittle, but little heavier than water, scentless and tasteless when pure, generally of a yellow or brown colour; non-conductors of electricity, but themselves readily electric by friction. Combustible in the open air with much flame and black smoke, which, when collected, condenses into the well-known substance lamp-black. The substances in this class are common resin, colophony, pitch, balsam of copiba, copal, elemi, mastic, sandarach, dragon's blood, some viscid turpentine, Burgundy pitch, and a few others. For analyses of these bodies, see Gay Lussac and Thenard, *Recherches*, and some curious experiments by Mr. Hatchett, *Phil. Trans.* vol. xciv., xcv., xevi.

(1018.) *Gum Resins.* These substances are exudations from the bark and branches of trees; they are much used in Medicine and in the Arts. In this class are assafoetida, gum ammoniac, galbanum, olibanum, myrrh, opoponax, scammony, aloes, luc, and a few others. For the Natural History of these bodies, consult any good *Pharmacopæia*.

(1019.) *Balsams.* These, like the last mentioned, are in fact compound bodies, and for the most part consist of resin, benzoic Acid, with some oil peculiar to each. For examples we may name balsam of Peru, balsam of Tolu, benzoin, and storax.

(1020.) *Caoutchouc.* This useful and curious substance is the inspissated juice of three or four East Indian and American plants.

(1021.) *Wax.* Many plants seem to elaborate this substance by vessels proper for its production and deposition; it exists in the pollen of plants, and hence is collected in large quantities by bees. A question has arisen whether these animals only collect wax, or have the power of secreting it: the latter is the opinion of Mr. Huber.

(1022.) *Camphor.* This substance exists in various species of the genus *Laurus*, but is principally obtained in Japan from the *Laurus camphora*. It is subsequently refined in Europe by sublimation. See Clemandot, *Jour. de Pharmacie*, vol. iii. p. 323; *An. de Ch.* vol. xxi., xxxvii., xl., xlviii.; *An. de Ch. et Ph.* vol. iv. p. 310, and vol. viii. p. 78; Chevreul, *An. de Ch.* vol. lxxiii. p. 167.

(1023.) *Alcohol.* This substance well known in an impure state as spirits of wine, is then combined with water from which it is by no means easy to effect a separation. Alcohol is a product formed during the vinous fermentation: hence it exists in wine, beer, &c. To this substance these Liquids owe their intoxicating properties. The Specific Gravity of the purest alcohol, supposed anhydrous, is 0.796 at 60° Fahrenheit. When its Specific Gravity is 0.820, it boils at 176° Fahrenheit, and is highly inflammable. It is not clear that alcohol has never been frozen: Mr. Walker found it fluid at - 91° Fahrenheit. Alcohol dissolves potassa, soda, lithia, ammonia, and the vegetable alkalis, but does not act on the earths, or metallic oxides. Whether alcohol existed in wines as such, or was formed during their distillation, was long doubted; but the question was at length decided in the affirmative by some good experiments of Mr. Brande. On the modes of obtaining pure Alcohol see Gay Lussac, *An. de Ch.* vol. lxxxvi. A curious fact is mentioned in the *Journal of Science*, vol. xviii., viz. that if impure alcohol, contained in an ox's bladder, be suspended in the air, the water escapes, and the alcohol becomes concentrated. On the constitution of alcohol, see Saussure, jun. *An. de Ch.* vol. lxxxix. For strength of alcohol, see Table IX.

(1024.) *Æthers.* M. Thenard divides æthers into three classes: 1. those which consist of hydrogen, carbon, and oxygen; and are formed by the mutual action of certain Acids, alcohol, and water; 2. those which result from the combination of bicarburetted hydrogen with some Acid employed in their formation; and 3. those which consist of a direct union of alcohol with the Acid employed for their formation.

Of the first kind are sulphuric, phosphoric, arsenic, and fluo-boric. Of the second kind are hydrochloric, hydriodic, and hydro-fluoric. And of the third, nitric, and several produced by vegetable Acids.

As an example of this sort of substance, take sulphuric æther. Sulphuric Acid is added to an equal quantity of alcohol in a glass flask, but with great caution agitating it on each addition of Acid. A gentle heat is then applied, and the æther distils over, and is condensed in a cool receiver. Sulphuric æther has a pungent, and to most persons an agreeable odour. Its

Chemistry. Specific Gravity is about 0.7, and it is highly volatile. Consult Thenard, *Système*, vol. iv. p. 146; *Mém. d'Arcueil*, vol. i. ii.

(1025.) *Bitumens, Coal, Amber, &c.* It would require volumes to do justice to the Natural History of this important class of substances, which we must dismiss after a few lines of description. All are generally believed to be the results of the spontaneous decomposition of Vegetable matters, though the period at which they must have flourished is, in many cases, very remote. Bitumens proper, and naphtha, a more limpid and volatile bitumen, (containing no oxygen,) are generally found as exudations from the earth in parts subject to the operation of volcanic fires. Coal is found in extensive deposits in several parts of the earth, and forms by far the richest mineral treasure of England. Amber is found in masses, chiefly on the Northern European shores; and on the coast of Sicily, near the mouth of the Giarretta. Retinasphalt, first described by Mr. Hatchett in the *Phil. Trans.* for 1804, is found in small quantity with brown coal at Bovey, in Devonshire.

### CLASS III.

*Vegetable Proximate Elements in which the Oxygen and Hydrogen are in just proportion for the formation of water.*

All substances in this class are solid, heavier than water, scentless, and have no action on Vegetable colours. They are not volatile, but are altogether decomposed by heat. When placed in contact with 100 or 150 times their volume of chlorine, they become carbonized in a few days, and the chlorine passes to the state of hydrochloric Acid Gas.

(1026.) *Sugar.* Of this substance four kinds at least are recognised by Chemists: that of the cane, beet-root, and other such Vegetables; of the grape, and other fruits; of some of the Fungi; and that which is found in the urine of persons labouring under one variety of *Diabetes*.

(1027.) *Honey* is a substance greatly analogous to sugar in its nature, secreted by some plants, and collected by bees. It has been questioned how far the process performed by this interesting animal is secretive or merely a process of mechanical separation. On this point see Huber, *Jour. de Phys.* 1804.

(1028.) *Mannite.* This name is given by M. Thenard to the saccharine principle of manna, an exudation from some species of ash.

(1029.) *Asparagine.* The vegetable principle peculiar to asparagus; discovered by MM. Vauquelin and Robiquet. See *An. de Ch.* vol. lvii. p. 88.

(1030.) *Starch.* This name is applied generally to a substance found in a great number of roots and grains; and forming a very considerable share of their nutritive substance. Consult Saussure, *An. Phil.* vol. vi. and *An. de Ch. et Ph.* vol. xi.; Caventou, *An. de Ch. et Ph.* vol. xxxi.

(1031.) *Gum.* This useful proximate element is obtained as an exudation from several plants. The most plentiful variety is from the *Mimosa* genus, growing in hot Countries, and well known as Gum Arabia. The gum of the plum and cherry tree, and even the mucilage obtained by macerating linseed, are believed to be varieties of the same substance. See Bostock, *Nich. Jour.* vol. xviii.

(1032.) *Lignin, or Woody Fibre.* The main solid

constituent of all trees and plants. See Bracconot, *Part III. An. de Ch. et Ph.* vol. xii.

### CLASS IV.

*Vegetable Colouring Principles.*

The substances in this class are found in various parts of Vegetables; and as they are of great importance in the Arts, they have formed the subject of numerous experiments by the most expert Chemists.

(1033.) *Hæmatine.* The colouring principle of logwood, described by M. Chevreul, *An. de Ch.* vol. lxxxi. p. 128.

(1034.) *Carthamine.* Such might serve for the name of a deep-red colouring matter obtained from the *Carthamus tinctorius*, but which has as yet been little examined.

(1035.) *Indigo.* This most valuable and curious Vegetable product is obtained chiefly from a genus of plants produced in Asia and America, and also of inferior quality from the *Isatis tinctoria*, which has long been cultivated in Europe. See Chevreul, *An. de Ch.* vol. lxvii. p. 29; also *ib.* vol. lxxii. and lxxviii.

(1036.) *Polychroule.* Such is the name given by MM. Bouillon Lagrange and Vauquelin to the colouring principle of saffron, in consequence of the great variety of tints which it is capable of assuming. (πολλὴς, many, χροῖα, colour) See their Memoir, *An. de Ch. et Ph.* vol. lxxx. and that of M. Henri, *Jour. de Phar.* vol. vii.

(1037.) *Carmine.* This beautiful pigment is formed from the colouring principle of cochineal with alumina or oxide of tin for a base. Cochineal is obtained from an insect which feeds on the leaves of several species of *Cactus*. See Pelletier and Caventou, *Jour. de Phar.* vol. iv.

Other red dyes are obtained from madder, Brazil wood, &c. The principal yellow dyes, are *Reseda luteola*; quercitron bark; fustic; turmeric; fernambouc, &c. &c.

Upon a knowledge of these substances the Art of Dyeing depends. See Chaptal, *Chimie appliquée aux Arts*; Bancroft, *on Permanent Colours*; Berthollet, *Elémens de l'Art de la Teinture*; Henry, *Manch. Mem.* vol. iii.; and Thenard and Rozard, *An. de Ch.* vol. lxxiv.

### CLASS V.

*Vegetable Proximate Elements not noticed in any of the preceding Classes.*

Many substances which will be, or might be, here mentioned, will, most probably, upon further investigation, require to be placed in some one of the preceding classes; but this is an intricate department of the Science, and in it there have been but few zealous labourers.

(1038.) *Gluten.* This substance is sometimes termed vegeto-animal, from partaking of the nature and properties of animal matter. It is a tough, elastic substance, most readily obtained by washing away the facula, mucilage, &c. from paste made of any kind of corn. M. Taddei has recently stated gluten to consist of two distinct principles, *gliadine*, soluble in alcohol, and *zymome*, which has not that property. *An. Phil.* vol. xv.

(1039.) *Yeast.* The peculiar principle of this substance is called by some writers *Ferment*. Its distinctive property is that of exciting fermentation in Vegetable matter under certain conditions.

(1040.) *Tannin.* This curious and important body

**Chemistry.** exists in the bark of trees, in the gall-nut, and in the juices of some plants, as the Catechu and Kino; and chiefly in such leaves as possess astringent properties. Tannin is soluble in water, and is remarkable for the combinations which it forms both with Acids and alkalis. It has a strong affinity for oxide of iron; and upon the durable, insoluble compound which it forms with gelatine depends the valuable Art of the Tanner.

Mr. Hatchett discovered a mode of forming tannin artificially by the action of nitric Acid on charcoal and some bituminous substances. See Hatchett, *Phil. Trans.* or *An. de Ch.* vol. lvii.; Chevreul, *An. de Ch.* vol. lxxii. p. 113, and vol. lxxiii. p. 36.

(1041.) *Amidine* rests on the authority of M. Saussure, who obtained it from starch. *An. de Ch. et Ph.* vol. xi.

(1042.) *Bassorine*. The principle of gum bassora. See Vauquelin, *Bulletin de Phar.* vol. iii. p. 56. *Thèse sur les Gommés Résines*, Pelletier, p. 23.

(1043.) *Bryonine*. A principle in the juice of the bryony plant. See *Jour. de Chim. Méd.* vol. i. p. 345, 502.

(1044.) *Cathartin*. The active principle of senna. *An. de Ch. et Ph.* vol. xvi. p. 20.

(1045.) *Cerine*. This name is proposed by M. Chevreul for a fatty substance found in cork.

(1046.) *Cytisine*. A substance like gum arabic, obtained by MM. Chevallier and Lassaigne from the seeds of the *Cytisus laburnum*. *Jour. de Phar.* vol. iv. p. 340, and vol. vii. p. 235.

(1047.) *Extractive*. This name is perhaps rather vague: it has been said that saffron, by maceration in hot water, affords the type of true extractive matter; but the term has been frequently applied to whatever could be extracted from a plant by a similar process, provided no peculiar principle were recognised.

(1048.) *Fungin*. The name applied by M. Braconnot to the solid matter of the Fungus tribe.

(1049.) *Jelly*. This term is given to the gelatinous matter which is found in many fruits: the currant and gooseberry afford good examples.

(1050.) *Gentianin*. The principle found by MM. Henri and Caventou in the gentian root. *Jour. de Phar.* vol. vii. p. 173.

(1051.) *Hordein*. A principle found by M. Proust in barley. *An. de Ch.* vol. xvi. p. 294.

(1052.) *Inuline*. This name was proposed by Dr. Thomson for a principle discovered by M. Rose in the *Inula Helenium*, and subsequently in some other roots.

(1053.) *Lupuline*. First recognised by Dr. Ives of New York in the hop; and subsequently examined by MM. Planché, Payen, and Chevallier. *Jour. de Phar.* vol. viii. p. 209.

(1054.) *Piperine*. A principle discovered by M. Orsted in common pepper, and by him supposed an alkali. M. Pelletier, however, did not find it possessed of alkaline properties.

(1055.) *Olivine*. This substance was discovered by M. Pelletier in the gum of the olive tree. *Jour. de Phar.* vol. ii. p. 337.

(1056.) *Sarcocolle*. A substance which exudes from the *Penæa sarcocolla*, a tree of Northern Africa.

(1057.) *Suberine*. The name proposed by M. Chevreul for the cellular tissue of cork.

(1058.) *Ulmín*. Discovered, in 1797, by M. Vauquelin in a substance often seen to issue from the bark of the elm. See *An. de Ch.* vol. xxi. p. 44; also *An. de Ch. et Ph.* vol. xii.

(1059.) *Caffein*. Recognised by M. Robiquet in coffee; and independently by MM. Pelletier and Caventou. See *Jour. de Phar.* May, 1826.

(1060.) *Colocynthin*. The name given by Vauquelin to what he considered the peculiar principle of the colocynth apple. See Brandes, *Jour.* vol. xviii. p. 400.

#### FERMENTATION.

Certain Vegetable Proximate Elements, such as alcohol, some pure Acids, and alkalis, may be left to themselves and undergo no changes. Others, such as sugar, gum, starch, &c., can be left but a very short time before spontaneous changes commence among their ultimate elements, and new combinations result. To these spontaneous changes the name of Fermentation is generally applied. It is to be remembered that so long as healthy, organic life is found in Vegetable matter, Fermentation does not commence. Four sorts of products give names to the four recognised kinds of Fermentation.

(1061.) *Saccharine Fermentation*. The only real instance of this process is seen in starch, which by being kept in a moist state for a considerable time is gradually converted into sugar. Saussure, *An. de Ch. et Ph.* vol. xi. p. 379.

(1062.) *Vinous Fermentation*. It is generally supposed that the Vinous Fermentation depends entirely upon the conversion of sugar into alcohol; and that in order that the process should take place, water and yeast must be present with a certain elevation of temperature. The conversion of the elements of the sugar into alcohol has been elegantly illustrated by M. Gay Lussac, *An. de Ch.* vol. xcv. p. 317. In the process as it takes place in the juices of fruits, yeast is not added, as there seems to be present some principle capable of commencing the operation spontaneously. The well-known operations of making beer, wine, and spirits, depend upon the formation of alcohol from Vegetable decoctions, or from the juices of fruits and trees. See Colin, *An. de Ch. et Ph.* vol. xxviii. xxx.; on wine, *An. de Ch. et Ph.* vol. xviii. p. 380; Duportal, *An. de Ch.* vol. lxxvii. p. 178.

(1063.) *Acetous Fermentation*. Paste and numerous Vegetable substances, especially of a mucilaginous nature, become sour by keeping; and this whether they be exposed to the air or not. This, though it arises from the conversion of their elements into acetic Acid, is not to be considered the true Acetous Fermentation. The process to which the name is strictly applied, takes place upon some Liquid in which alcohol is existent from having previously undergone the vinous fermentation; or, which amounts to the same thing, alcohol may be mixed with water. For the Acetous Fermentation to take place, some elevation of temperature is requisite, and the presence of yeast, or some such substance, in order to determine the commencement of the process. A temperature of from 60° to 80° Fahrenheit succeeds best. The operation depends on the conversion of alcohol into acetic Acid.

(1064.) *Putrefactive Fermentation*. Vegetable substances, when exposed to a certain degree of warmth and moisture, frequently undergo this action, which consists in a decomposition of the bodies, and a recombination in some other form or forms. Generally speaking, the more complex the body the more moisture is present, and the more readily does this process take place. Those substances, however, in which carbon and hydrogen prevail, such as alcohol, resins, and oils, are

**Chemistry.** the least subject to this process, and some are not liable to it in any degree. By the Putrefactive Fermentation most disagreeable effluvia are produced, and the substances are resolved into carburetted hydrogen Gases; carbonic Acid; ammonia, if nitrogen be present; water; acetic Acid in some cases; and solid carbonaceous matter.

## CHAPTER II.

### CHEMISTRY OF ANIMAL BODIES.

The substances which we shall enumerate in this Chapter consist of oxygen, hydrogen, carbon, and nitrogen, as their chief elements; but small portions of other substances are united with these, so as to produce important modifications in their general properties. The first three of our classes will consist of simple proximate elements; while the last class will contain those complex Fluids or Solids, which are distinctly recognised as ministering to the functions of animal life.

#### CLASS I.

##### *Substances neither acid nor oleaginous.*

These bodies are altogether decomposed by destructive distillation, and produce water, carbonic Acid Gas, carbonate of ammonia, compounds of cyanic Acid, with ammonia in very minute quantities, Gaseous oxide of carbon, a fetid, animal oil, carburetted hydrogen Gas, nitrogen, and charcoal of a very dense texture. All are decomposable by nitric Acid.

(1065.) *Fibrin*. This is the main substance of muscular fibre, and it exists abundantly in blood and in the chyle. It is a white, solid, tasteless substance. See Chevreul, *An. de Ch. et Ph.* vol. xix.; Gay Lussac, *An. de Ch. et Ph.* vol. iv.; Berzelius, *An. de Ch. et Ph.* vol. lxxxviii.; Braconnot, *An. de Ch. et Ph.* vol. xiii.

(1066.) *Albumen*. This body is found in most animal Fluids and Solids; and almost pure in the white of the egg. Its most marked property is the power of coagulation by heat. See Chevreul, *An. de Ch. et Ph.* vol. xix.; Brande, *Phil. Trans.* 1809; Lassaigue, *An. de Ch. et Ph.* vol. xx.; Bostock, *Medico-Chir. Trans.* vol. ii.

(1067.) *Gelatine*. A substance readily soluble in water, and which forms a portion of most of the harder parts of animals. Glue is gelatine obtained by boiling the skins and hoofs of animals. Isinglass, a more pure or delicate sort, is obtained from the stomachs of certain fishes. Tannin has a strong affinity for it, and thus precipitates a solid compound of the two elements. See Gay Lussac and Thenard, *Rech.* vol. ii. p. 336.

(1068.) *Caseous Matter*. A substance existing in milk, and separated for the making of cheese. See Proust, *An. de Ch. et Ph.* vol. x. p. 29.

(1069.) *Urea*. A singular crystalline Solid which forms a very important ingredient of urine. See Proust, *Medico-Chir. Trans.* vol. viii. p. 529; Vauquelin, *An. de Ch.* vol. xxxii. p. 80.

(1070.) *Picromel*. A substance found in the bile. See Thenard, *Mém. d'Arcueil*, vol. i.; Berzelius, *Medico-Chir. Trans.* vol. iii.; Tiedemann and Gmelin.

(1071.) *Sugar of Milk*. This seems to be of the same nature with the sugar already mentioned (1026.) as occurring in the urine of diabetic patients. See Vau-

quelin, *Bulletin de Pharmacie*, vol. iii. p. 49; Vogel, *An. de Ch.* vol. lxxii. p. 156; Gay Lussac and Thenard, *Rech.*

#### CLASS II.

##### *Animal Acids.*

Among Animal matters Thenard names twenty-six Acids; nine differing altogether from fatty bodies; ten very considerably allied to them in Nature; three totally differing in origin and constitution; whilst some others are common to the Animal and Vegetable, or to the Animal and Mineral kingdoms.

*Acids more or less oxygenated, and differing considerably from fatty Bodies.*

(1072.) *Uric, or Lithic Acid*. This peculiar Acid was discovered by Scheele, in 1776; it exists with numerous other substances in the urine of many of the higher animals. See Henry, *Manch. Mem.* N. S. vol. ii.; Prout, *Medico-Chir. Trans.* vol. ix.

(1073.) *Puro-uric Acid*. If uric Acid be exposed to heat in a retort, this Acid is formed and volatilized. See Chevallier and Lassaigue, *An. de Ch. et Ph.* vol. xiii. p. 155.

(1074.) *Purpuric Acid*. This Acid was first recognised by Dr. Prout, and has exercised the ingenuity of some of the best Chemists, but at present it is not well understood. It is obtained by digesting pure uric Acid in diluted nitric Acid. See Prout, *Phil. Trans.* 1818; Vauquelin, *Mém. du Mus. d'Hist. Nat.* vol. vii. p. 253, and vol. ix. p. 155; Brugnatelli, *An. de Ch. et Ph.* vol. viii. p. 201; Lassaigue, *An. de Ch. et Ph.* vol. xxii. p. 334.

(1075.) *Rosacic Acid*. This substance has only been occasionally found in urine. See Proust, *An. de Ch.* vol. xxxvi. p. 258; Vauquelin, *An. de Mus. d'Hist. Nat.* vol. xvii. p. 133; Vogel, *Jour. de Phar.* vol. ii. p. 27.

(1076.) *Amniotic Acid*. This Acid was found by MM. Vauquelin and Buniva in analyzing the amniotic liquor of a cow. See *An. de Ch.* vol. xxxiii. p. 279.

(1077.) *Lactic Acid*. Scheele discovered this Acid in sour whey, in 1780. Berzelius considers it only the acetic disguised by the presence of Animal matter, and the same opinion is maintained by Tiedemann and Gmelin in their important Work on digestion, *Die Verdauung nach Versuche Heidelberg*, 1826.

(1078.) *Formic Acid*. This Acid exists in some species of ants. See Suenson, *Gehl. Jour.* vol. iv. p. 1; Gehlen, *An. de Ch.* vol. lxxxiii. p. 208; Döbereiner, *An. de Ch. et Ph.* vol. xx. p. 329.

(1079.) *Caseic Acid*. M. Proust, who discovered this acid substance, first called it Caseous Oxide, a name which more recent authors have changed to Caseic Acid. Proust, *An. de Ch. et Ph.* vol. x. p. 29.

(1080.) *Cyanic Acid*. We have already mentioned this Acid in another part of this Treatise (472.)

*The following Acids contain little Oxygen, and approach to fatty Substances in their Constitution and Properties.*

(1081.) *Sebacic Acid*. This Acid results from the distillation of fatty matters. M. Thenard first recognised it. See *An. de Ch.* vol. xxxix. p. 193.

(1082.) *Cholesteric Acid*. The sebaceous matter contained in the biliary calculi of man was termed *Cholestérine* by M. Chevreul. By treating this substance with nitric Acid, MM. Pelletier and Caventou



Chemistry. obtained a peculiar Acid, and gave to it the name of Cholesteric Acid. See *Jour. de Phar.* vol. iii. p. 292.

(1083.) *Stearic Acid*. M. Chevreul, the discoverer, so named this Acid from *στέαρ*, fat. He considers the formation of this Acid, and its union with an alkali, the essential process in the formation of soap. See Chevreul *sur les Corps Gras*.

(1084.) *Margaric Acid*. Discovered also by M. Chevreul, and named, from its pearly appearance, from *μαργαρίτης*, a pearl. This Acid exists in the fat of animals. See Chevreul, *op. cit.*

(1085.) *Oleic Acid*. Another of M. Chevreul's Acids, forming part of the same fatty matters, and capable, like the others, of saturating alkaline bases.

(1086.) *Phocenic Acid*. An Acid obtained by M. Chevreul, by acting on a peculiar oil with alkalis. This oil, called Phocenine, he obtained from the oil of the porpoise. (*Delphinus phocaena*.)

The *Butyric, Caproic, Capric, and Hircic Acids* have similar animal origin, and may be found in the Work of Chevreul. An Acid, called the *Cevadic*, is described by Pelletier and Caventon, *An. de Ch. et Ph.* vol. xiv. p. 71.

### CLASS III.

#### *Oleaginous Animal Substances.*

The substances referable to this class have the following general properties. They become liquid at very slight elevations of temperature; are insipid; very inflammable; insoluble in water; produce by distillation a small carbonaceous residuum, with much fetid oil; but by being passed in a state of vapour through a heated, porcelain tube, they deposit much carbon and evolve carburetted hydrogen Gas: they do not contain azote, and but little oxygen. M. Berard obtained a substance very similar in general properties, by transmitting a mixture of one volume of carbonic Acid, ten volumes of carburetted hydrogen, and twenty volumes of hydrogen through a red-hot tube. Döbereiner produced a similar effect from a mixture of coal Gas and aqueous vapour.

(1087.) M. Thenard says, that before the researches of M. Chevreul the notions formed relative to the fatty bodies were altogether inaccurate. "The fats were considered similar to the fixed oils, in being all as different from each other as they could be; that is to say, as much so as the various species of sugar. M. Chevreul has demonstrated that they are composed of a certain number of ultimate elements, and that the greater part differ from each other only by the relative proportions in which these exist. Of these he distinguishes eight species, to which he gives the following names: *Stearine, Oleine, Cetine, Colesterine, Ethal, Phocine, Butyrine, and Hircine*."

"These are divisible into four well-marked groups."

• "The first containing fatty substances which are not altered by alkalis, and are not capable of uniting together, *viz.* cholesterine and ethal."

"The second are convertible by alkalis into glycerine and oleic, margaric, or stearic Acid. Stearine of the sheen, stearine of man, and oleine."

"The third contains those which are transformed by alkalis into ethal, and into margaric and oleic Acids. Cetine."

• "The fourth comprehends those bodies which the alkalis change into glycerine, into volatile Acids when distilled with water, and into oleic Acid, or oleic and margaric Acids; *phocine, butyrine, hircine*."

It is not in our power to enter into the detail of these substances, so that we must refer our readers to the excellent Work of M. Chevreul *sur les Corps Gras*. Part III.

### CLASS IV.

#### *Complex Animal Substances.*

Besides the substances which have fallen under the preceding three Classes, there are certain other proximate elements, which enter more or less into the composition of Animal matters. Such are certain earthy or alkaline phosphates, carbonates, and sulphates; some Vegetable Salts with alkaline or earthy bases; some oxides; and some Salts formed by Animal Acids.

These, however, are inconsiderable in quantity, and are not exactly the bodies to which we turn our attention at this moment. We place in this class those Solids and Fluids which enter into the constitution of living animals. These substances are in general formed of numerous ultimate elements, which may be supposed to exist in groups, forming again proximate elements, by which the constitution of each substance, as blood, bile, &c., may be described.

#### *Secretions subservient to the function of Digestion.*

• (1088.) *Saliva*. A limpid Fluid, secreted by glands surrounding the mouth, and poured forth in considerable quantities, to be mixed with the aliments during mastication, and conveyed with the food into the stomach. See Berzelius, *An. de Ch.* vol. lxxxviii. p. 123; Lassaigne, *An. de Ch. et Ph.* vol. xix. p. 176.

(1089.) *Pancreatic Juice*. A Liquid secreted by the pancreas, a gland situated in the epigastric region, and conveyed by ducts opening into the duodenum. Immediate use unknown. See Leuret and Lassaigne, *Jour. de Chim. Médicale*, vol. i. p. 549.

(1090.) *Gastric Juice*. A Liquid, supposed to be secreted by the stomach, and unquestionably of great importance to the process of digestion. The solvent power of this Fluid is most remarkable. See Johnson, *Animal Chemistry*, vol. i. p. 180.

(1091.) *Bile*. A bitter, yellow, or greenish Liquid, secreted by the liver, and conveyed by ducts into the duodenum, to be mingled with the aliment which has passed thither from the stomach. See Johnson, *op. cit.*; Thenard, *Mém. d'Arcueil*, vol. i.; and the Work of Tiedemann and Gmelin.

#### *Substances immediately resulting from digested Aliments.*

(1092.) *Chyme*. The aliments are conveyed into the stomach, and there converted into a sort of pulpy matter, which is termed Chyme. For greater clearness, this substance is mentioned, though, as must be obvious, it is not a Chemical element of any sort; nor at all definite in its composition. See Marcet, *An. de Ch. et Ph.* vol. ii. p. 50; Prevost and Le Royer, *An. des Sciences Naturelles*, vol. iv. p. 481.

(1093.) *Chyle*. This name is applied to the Liquid absorbed by the lacteal vessels dispersed throughout the small intestines, and from them conveyed into the thoracic duct. Chyle is a white, opaque, milky-looking fluid. See Vauquelin, *An. de Ch.* vol. lxxxi. and vol. xciv.; Brande, *Phil. Trans.* 1812; Prout, *An. Philos.* vol. xiii.; Prevost and Le Royer, *ut sup.*

(1094.) *Blood*. The general appearance of this Fluid must be familiar to all: very numerous have been the researches made upon it by Chemists, especially

**Chemistry.** with reference to its colouring principle. Blood contains water, albumen, fibrin, a coloured Animal substance, a small quantity of fatty matter, and some Salts. When recent healthy blood is left at rest, it shortly separates into two portions, the one a transparent, yellowish Liquid called the serum; the other an opaque, reddish or brownish coagulum. The latest researches on this much agitated subject have proved that iron is the colouring principle of the Blood.

See Bostock, *Medico-Chir. Trans.* vol. ii. p. 166; Marcet, *Medico-Chir. Trans.* vol. iii. p. 231; Vauquelin, *An. de Ch. et Ph.* vol. xvi. p. 363; Prevost and Dumas, *An. de Ch. et Ph.* vol. xviii. p. 280, and vol. xxiii. p. 50; Brande, *Phil. Trans.* 1812; Engelhardt, *Edinb. Med. and Surg. Jour.* Jan. 1827; Berzelius, *Animal Chemistry*.

(1095.) *Urine.* This excrementitious Fluid is separated by certain glands, the kidneys, in order to be rejected from the system. This Liquid has been the subject of very numerous researches, in consequence of its important pathological relations. Consult Cruickshank in Rollo, on Diabetes, 2d Ed.; Berzelius, *Animal Chemistry*; Henry, *An. Phil.* vol. i.; Scheele, *Essays*; Vogel, *An. de Ch.* vol. xciii.; Prout, *An. Phil.* vol. xv.; Berzelius, *An. Phil.* vol. ii.; Nicolas, *An. de Ch.* vol. xlv.; Dupuytren and Thenard, *Ibid.* vol. lix.; Fourcroy and Vauquelin, *An. de Ch.* vol. xxxi. xxxii.; Wollaston, *Phil. Trans.* 1797; Berzelius, *An. de Ch.* vol. lxxxix.; Proust, *An. de Ch. et Ph.* vol. xiv.; Prout, *On the Nature and Treatment of Calculous Disorders*.

(1096.) *Intestinal Gases.* A mixture of varied constitution, examined by Chevreul and Magendie, *An. de Ch. et Ph.* vol. ii.; Lameyran and Fremy, *Bulletin de Pharmacie*, vol. i.

(1097.) *Fæces.* Excrementitious matter rejected from the system as not affording nutriment. See Berzelius, *An. de Ch.* vol. lxi. Of animals, Fourcroy and Vauquelin, *An. de Ch.* vol. lvi.; Vauquelin, *Ibid.* vol. xxix.; Proust, *An. de Ch. et Ph.* vol. xiii.

#### *Solid Parts of Animals.*

(1098.) *Cerebral Matter.* This constitutes the brain, spinal marrow, and nerves of animals. See Vauquelin, *An. Phil.* vol. i.

(1099.) *Skin.* This consists of three distinct layers. The exterior is the *epidermis*, or cuticle; the central is the *rete mucosum*; and the interior, which covers the muscles, is the true skin. See Johnson, *An. Ch.* vol. i.

(1100.) *Tendons, Membranes, and Ligaments.* These seem to consist almost entirely of gelatine.

(1101.) *Wool, Feathers, and Hair* appear, from the experiments of Vauquelin, to contain a peculiar Animal substance, with oil, sulphur, silica, iron, phosphate, and sulphate of lime.

(1102.) *Horn.* The hoofs and nails of animals consist chiefly of gelatine, with a matter analogous to coagulated albumen.

(1103.) *Muscle.* This the flesh is chiefly fibrin; but besides small portions of other ingredients, it contains a peculiar substance called *osmazome*; this produces the odour and nutritive portion of soups.

(1104.) *Bone, Teeth, and Shell.* Bone consists of a cartilaginous mass, rendered solid by interposition of earthy matter and gelatine. The earthy matter is chiefly phosphate and carbonate of lime. Teeth and ivory seem, by the analysis of Allen and Pepys, to contain a much larger proportion of earthy substance,

and less soluble matter. The shell of eggs, crabs, lobsters, and star-fish consists chiefly of carbonate of lime, with a little phosphate and Animal matter. In the shells of oysters and ordinary *Mollusca*, the phosphate of lime is absent.

#### *Glandular and Membranous Secretions.*

(1105.) *Lymph.* A colourless and transparent Liquid which circulates through a certain order of vessels, which seem to commence near the extreme ramifications of the arteries, and, uniting to form larger channels, return the lymph into the thoracic duct. See Brauder, *Phil. Trans.* 1812; Leuret and Lassaigne, *Jour. de Ch. Méd.* vol. i. p. 155.

(1106.) *Synovia.* A Liquid secreted by a system of glands for the purpose of lubricating the joints, and the ligaments uniting them. See Margueron, *An. de Ch.* vol. xiv.; Vauquelin, *Jour. de Phar.* vol. iii.

(1107.) *Fætal Liquids.* These Fluids are contained within the respective membranes surrounding the *fætus*. The exterior being the *chorion*, the intermediate one the *allantois*, and the interior the *amnion*. See Dulong and Labillardiere, *Procès-Verbal de la Séance Publique de l'Ecole d'Alfort*, 1817; Lassaigne, *An. de Ch. et Ph.* vol. xvii. p. 295.

(1108.) *Humours of the Eye.* Of these there are three: 1st, the *aqueous*, in the anterior chamber between the transparent cornea and the iris, and also in the posterior chamber between the iris and the crystalline lens; 2dly, the *crystalline lens* itself; and 3dly, the *vitreous humour*, occupying a considerable space at the back of the crystalline lens. See the experiments of Chenevix, Nicolas, and Berzelius, *Bibl. Brit.* vol. liv.; *An. de Ch.* vol. liii. p. 307, vol. lxxxvii., and lxxxviii. p. 135.

(1109.) *Tears.* A limpid Fluid, analyzed by MM. Fourcroy and Vauquelin, *An. de Ch.* vol. x. p. 113.

(1110.) *Animal Mucus.* This Liquid is not confined to any particular part of the body, nor is it secreted by any perceptible glandular tissue, but the secretion takes place at the surface of all mucous membranes. It is most abundant in the nose, mouth, œsophagus, stomach, intestines, urinary passages, &c. See Fourcroy and Vauquelin, *An. de Ch.* vol. lxvii. p. 26; Berzelius, *Ibid.* vol. lxxxviii. p. 113.

(1111.) *Perspiration.* The Fluid issuing from the system under this name is at all times passing off, but sometimes as a vapour, when it is called the insensible perspiration; at other times in such quantities as to collect in moisture on the surface, when it is called sweat. See Berzelius, *An. de Ch.* vol. lxxxix. p. 20; Seguin, *Ibid.* vol. xc. p. 14.

(1112.) *Milk,* a Fluid secreted by appropriate glands in animals of the class *Mammalia*, and designed for the sustenance of their young, contains three distinct proximate principles, the cream, curd, and whey. See Scheele, *Mém.* vol. ii.; Fourcroy and Vauquelin, *Mém. de l'Institut*, vol. vi. p. 22.

(1113.) *Spermatic Fluid.* For analyses, &c., see *Jour. de Phys.*, Jan. 1784, p. 437; Vauquelin, *Ibid.* p. 58. sem. 2. 1791; Spallanzani, *Tracts*, 1799; Vauquelin, *An. de Ch.* vol. ix. p. 64; Prevost and Dumas, *An. de Hist. Nat.* vol. i. p. 167, 274.

*Concretions found in the Animal System, and all resulting more or less from diseased Action.*

(1114.) *Biliary.* Gall stones, as they are called, are

Chemistry. concretions formed in the gall bladder, and found there or in the biliary ducts, where they, at times, produce serious effects. See Thenard, *Mém. d'Arcueil*, vol. i.; Orfila, *An. de Ch.* vol. lxxxiv. p. 34; Caventou, *Jour. de Phar.* vol. iii. p. 369; Chevreul, *Jour. of Science*, vol. xviii. p. 403; Johnson, *An. Ch.* vol. ii.

(1115.) *Urinary.* From the constituent principles of the urine these calculi are separated either in the kidneys primarily, or in the bladder by deposition upon some nucleus. They exist also in the prostate gland, which in such cases is probably the seat of their origin. On this important subject consult Scheele's *Essays*; Wollaston, *Phil. Trans.* 1797 and 1810; Fourcroy and Vauquelin, *Mém. de l'Inst.* vol. ii. p. 112; *An. de Mus. Nat.* vol. i. p. 93; Pearson, *Phil. Trans.* 1798; Brande, *Phil. Trans.* 1802; Marcet, *Essay on the Chemical History and Medical Treatment of Calculous Disorders*, 1817; Prout, *Inquiry into the Nature and Treatment of Gravel, Calculus*, &c. 2d edit. 1825; Henry, *An. Phil.* vol. xv. p. 107.

(1116.) *Arthritic.* These calculi are formed chiefly at the joints of gouty individuals. See Wollaston, *Phil. Trans.* 1797; Vogel, *Bulletin de Pharmacie*, vol. iii. p. 568; Laugier, *Jour. de Chim. Méd.* vol. i. p. 6.

(1117.) *Salivary.* Concretions occur in the salivary glands. Those examined are chiefly from the larger animals. See Lassaigne, *An. de Ch. et Ph.* vol. xxx. p. 332; *Jour. de Pharm.* vol. iii. p. 208; Laugier, *Jour. de Chim. Méd.* vol. ii. p. 105.

(1118.) *Pancreatic.* Calculi have been found in the pancreas, but their nature is almost unknown.

(1119.) *Pineal.* In the pineal gland very small calculi are frequently met with; according to Vauquelin, they contain phosphate of lime and animal matter.

(1120.) *Pulmonary.* Fourcroy has mentioned these calculi as found in the lungs of old persons, especially of those subject to arthritic formations; and he states that they are sometimes expectorated in small fragments.

(1121.) *Intestinal.* Concretions, sometimes resulting from the intertexture of indigestible substances, and sometimes from the true deposition of calculous matter, are described by the following authors. Fourcroy and Vauquelin, *Mém. du Mus. d'Hist. Nat.* vol. iv. p. 329; Marcet, *op. cit.*; Braconnot, *An. de Ch. et Ph.* vol. xx. p. 194; Robert, *Jour. de Phar.* vol. vii. p. 161; Lassaigne, *Jour. de Chim. Méd.* vol. iii. p. 119; Dublanc, *Ibid.* p. 496.

### CHAPTER III.

#### FUNCTIONS OF ANIMAL AND VEGETABLE LIFE.

##### Animal Life.

(1122.) The changes produced upon the various substances employed for the support of life are mainly connected with physiological researches, but to such researches Chemistry lends an important and even necessary assistance. Food and air are essential to the continuation of vitality. The former undergoes mastication, is mixed with saliva, and then descends into the stomach. It is there acted upon by the gastric juice, and the mass is termed chyme. The changes

produced upon the food during the process of digestion have exercised the ingenuity of many physiologists. Among the most recent and most remarkable discoveries, is that made by Dr. Prout, and published in the *Philosophical Transactions* for 1824, of the production of hydrochloric Acid during this process. Passing thence into the intestines the bile and pancreatic juice are added to it. Here it is separated into excrementitious matter to be rejected from the system, and chyle to be absorbed by a peculiar set of vessels and applied to nutritive purposes.

From this period the chyle forms a part of the circulating system. From the lacteal vessels it is poured into the thoracic duct, but whether in the process it undergoes any further change is not certain. By the thoracic duct the chyle is conveyed to the larger veins proceeding to the heart; the blood is thence transmitted to the lungs where the essential process of aeration takes place. It is then returned to another cavity of the heart, from whence it is propelled through the arterial system to the utmost extremities of the frame, and having there supported and excited all the functions of vitality in every organ, it is returned again by the veins to be mixed with fresh supplies of energetic matter, and again diffused throughout the body.

The changes produced upon the blood by its passage through the lungs have formed the subject of numerous experiments. It seems well established that among these the absorption of oxygen is most important and extensive. Hence the necessity of the presence of oxygen Gas in air to fit it for respiration; and the diminution of that element which is found to take place in air that has undergone the process. Besides that portion of oxygen which goes to aerate the blood, and to prepare it for the arterial circulation, another portion is converted into carbonic Acid Gas, and emitted with the aerial mass that is returned into the atmosphere by expiration.

##### Vegetable Life.

(1123.) The germination of a seed is the first step towards Vegetable life. The seed itself consists of a cuticle enveloping the germ, and the cotyledons, or seed-lobes. The germ consists of the radicle and the plumula. Moisture, air, and a certain degree of heat are requisite for vegetation. The heat must exceed 32° Fahrenheit, and must not reach that of boiling water. Light, which is of first-rate importance to the growing plant, is injurious to germination. This process consists in the developement of the parts already named. The radicle descends into the earth in search of nutriment; the plumula expands into the stem and first elements of the future tree; the cotyledons afford nutriment in the early stages of vitality.

The process of Vegetable assimilation is this. The root absorbs moisture and soluble Vegetable matter, the food of the plant. The juices so imbibed are carried up through certain vessels, and spread by ramifications throughout the leaves, which, acting as aerating surfaces, or lungs, prepare the juices for strict assimilation. The juices are then transmitted to the proper vessels, returned through the inner bark, and thence employed in the increase of the plant. In these juices the peculiar properties of each plant chiefly reside.

## PART IV

## CHEMICAL ANALYSIS. CONNECTION WITH MINERALOGY.

Chemistry.

(1124.) The object of Chemical analysis is the separation of all compound bodies into their proximate or ultimate elements. For this purpose the first step is the application of tests for the purpose of ascertaining what the substance before the analyst may be, and what elements enter into its composition. When the presence of certain elements are ascertained, it becomes necessary to devise processes by which each of these may be separated from the rest and its quantity ascertained. The meeting with a substance no longer capable of qualitative division, and differing in properties from all substances previously known, is the discovery of a new element, and forms one of the highest rewards to the industry of the analytical Chemist. To enter upon these branches of the subject, even in abstract, would extend far beyond the limits to which we are confined. On the subject of tests the reader will find Payen and Chevallier, *Traité des Réactifs*, valuable guides. On the subject of analysis he will do well to consult the last Volume of M. Thenard's *Traité de Chimie*, or a translation of it by Mr. Children. Most important information will always be obtained by consulting the numerous analyses in the periodical *Transactions* and *Journals*.

It has not been unusual in Treatises on Chemistry to insert descriptive catalogues of mineral substances.

With such a plan we should not concur even if our limits permitted; for it would seem that by so doing the respective boundaries of Mineralogical and Chemical Science are confounded. It is the province of the Mineralogist to describe the substances with which he may meet according to all those external and physical characteristics by which minerals are distinguished from each other. In some, but in very few cases, Chemistry has made a further separation; but in all cases the history of a mineral is incomplete unless also its Chemical analysis be given. This it is the province of the Chemist to furnish. Thus the full description of the mineral results from the application of two distinct branches of Science, generally more or less united among the attainments of the same individual but not essentially coexistent. It would not be difficult to name Chemists of first-rate excellence who are not Mineralogists; nor, on the contrary, to point out able Mineralogists who are utterly incompetent to the analysis of the mineral they describe. Unquestionably the wants of the Mineralogist frequently demand the employment of the skill of the Chemist, but the Chemical examination of any substance artificially prepared and placed before him, is as justly the task of the latter, that of the native produce of the rock and the mine.

Part IV.

### COLLECTION OF TABLES.

#### TABLE I.

*Table of the Specific Gravity of Gases. See (75.)  
(From Henry's Elements.)*

Barometer 30°, Thermometer 60° Fahrenheit.

Names of Gases.	Sp. Gr.	Weight of 100 cubic inches.	Authorities.
Atmospheric air	1.0000	30.500	Shuckburgh.
Ditto	1.0000	30.199	Brande.
<i>Simple Gases.</i>			
Oxygen	1.1088	33.820	Allen and Pepys.
Ditto	1.1111	33.888	Thomson.
Ditto	1.1026	33.629	Berzelius & Dulong.
Chlorine	2.5082	76.500	Davy.
Ditto	2.5000	76.250	Thomson.
Iodine (vapour)	8.6780	244.679	Gay Lussac.
Ditto	8.6111	262.6308	Thomson.
Hydrogen	0.0694	2.116	Ditto.
Ditto	0.0688	2.098	Berzelius & Dulong.
Nitrogen	0.9722	29.625	Thomson.
Ditto	0.9760	29.768	Berzelius & Dulong.
Carbon (vapour)	0.4166	12.6083	Gay Lussac.
Sulphur (ditto)	1.1111	33.888	Thomson.
Phosphorus (ditto)	0.8333	25.416	Ditto.
<i>Compound Combustible.</i>			
Ammonia	0.5960	18.18	Allen and Pepys.
Ditto	0.5902	18.003	Thomson.
Ditto	0.5912	18.03	Berzelius & Dulong.
Carburetted hydrogen	0.5555	16.911	Thomson.
Ditto	0.5590	17.049	Berzelius & Dulong.
Olefiant	0.9722	26.652	Thomson.
Ditto	0.9804	29.90	Berzelius & Dulong.
Phosphuretted hydrogen	0.9027	27.537	Thomson.
Bihydroguret of phosphor.	0.9722	29.652	Ditto.
Sulphuretted hydrogen	1.1805	36.007	Ditto.
Bisulphuret of carbon (vapour)	2.6388	80.486	Ditto.
Arsenuretted hydrogen	0.5290	16.130	Tromdorff.
Cyanogen	1.8055	55.069	Gay Lussac.
Ditto	1.8188	55.473	Berzelius & Dulong.
Ether sulphuric (vapour)	2.5808	78.711	Ditto.
Ditto muriatic (ditto)	2.2190	67.679	Thomson.
Ditto hydriodic (ditto)	5.1750	156.97	Ditto.
Ditto chloric (ditto)	3.1750	105.257	Ditto.
Alcohol (ditto)	1.6001	48.812	Berzelius & Dulong.
Turpentine, oil of (ditto)	5.0130	152.896	Thomson.
<i>Oxides.</i>			
Aqueous vapour	0.6250	19.062	Gay Lussac.
Nitrous oxide	1.5277	46.597	Thomson.
Ditto	1.5273	46.582	Berzelius & Dulong.
Nitric oxide	1.0416	31.770	Thomson.
Carbonic oxide	0.9722	29.652	Ditto.
Ditto	0.9727	29.607	Berzelius & Dulong.
<i>Acids.</i>			
Carbonic	1.5277	46.597	Thomson.
Ditto	1.5210	46.481	Berzelius & Dulong.
Chlorocarbonic (phosgene)	3.4722	105.902	Thomson.
Chlorocyanic (vapour)	2.1520	65.636	Ditto.
Fluoboric	2.3611	72.013	Ditto.
Fluosilicic	3.611	110.138	Ditto.
Hydriodic	4.340	132.378	Ditto.
Hydrocyanic	0.9375	28.572	Ditto.
Muriatic	1.2847	39.183	Ditto.
Nitric	3.75	114.375	Davy.
Sulphurous	2.2222	67.777	Thomson.
Sulphuric (vapour)	2.7777	84.698	Ditto.

#### TABLE II.

*Exhibiting the Specific Gravity of Muriatic Acid of determinate Strengths.*

Atoms of Acid.	Atoms of Water.	Acid in 100.	Specific Gravity.
1	6	40.659	1.203
1	7	37.000	1.179
1	8	33.945	1.162
1	9	31.346	1.149
1	10	29.134	1.139
1	11	27.206	1.1285
1	12	25.517	1.1197
1	13	24.025	1.1127
1	14	22.700	1.1060
1	15	21.512	1.1008
1	16	20.442	1.0960
1	17	19.474	1.0902
1	18	18.590	1.0860
1	19	17.790	1.0820
1	20	17.051	1.0780

From Thomson's *First Principles*, vol. i. p. 87.

#### TABLE III.

*Of the Quantity of real or dry Muriatic Acid in 100 parts of the liquid Acid, at successive Specific Gravities. By Dr. Ure, Thomson's *Annals*, vol. x. p. 371*

Sp. Gr.	Acid in 100.	Sp. Gr.	Acid in 100.	Sp. Gr.	Acid in 100.
1.1920	28.30	1.1272	18.68	1.0610	9.05
1.1900	28.02	1.1253	18.39	1.0590	8.77
1.1881	27.73	1.1233	18.11	1.0571	8.49
1.1863	27.45	1.1214	17.83	1.0552	8.21
1.1845	27.17	1.1194	17.55	1.0533	7.92
1.1827	26.88	1.1173	17.26	1.0514	7.64
1.1808	26.60	1.1155	16.98	1.0495	7.36
1.1790	26.32	1.1134	16.70	1.0477	7.07
1.1772	26.04	1.1115	16.41	1.0457	6.79
1.1753	25.75	1.1097	16.13	1.0438	6.51
1.1735	25.47	1.1077	15.85	1.0418	6.23
1.1715	25.19	1.1058	15.56	1.0399	5.94
1.1698	24.90	1.1037	15.28	1.0380	5.66
1.1679	24.62	1.1018	15.00	1.0361	5.38
1.1661	24.34	1.0999	14.72	1.0342	5.09
1.1642	24.05	1.0980	14.43	1.0324	4.81
1.1624	23.77	1.0960	14.15	1.0304	4.53
1.1605	23.49	1.0941	13.87	1.0285	4.24
1.1587	23.20	1.0922	13.58	1.0266	3.96
1.1568	22.92	1.0902	13.30	1.0247	3.68
1.1550	22.64	1.0883	13.02	1.0228	3.39
1.1531	22.36	1.0863	12.73	1.0209	3.11
1.1510	22.07	1.0841	12.45	1.0190	2.83
1.1491	21.79	1.0823	12.17	1.0171	2.55
1.1471	21.51	1.0805	11.88	1.0152	2.26
1.1452	21.22	1.0785	11.60	1.0133	1.98
1.1431	20.94	1.0765	11.32	1.0114	1.70
1.1410	20.66	1.0746	11.04	1.0095	1.41
1.1391	20.37	1.0727	10.75	1.0076	1.13
1.1371	20.09	1.0707	10.47	1.0056	0.85
1.1351	19.81	1.0688	10.19	1.0037	0.56
1.1332	19.53	1.0669	9.90	1.0019	0.28
1.1312	19.24	1.0649	9.62	1.0000	0.00
1.1293	18.96	1.0629	9.34		

\* Note by Dr. Henry. The data on which this Table is founded were obtained by saturating different bases with known quantities of muriatic Acid, Specific Gravity 1.192, and ascertaining the weight of the dry products. For example, 100 grains of such Acid gave 60.61 grains of dry common salt, which, on the old theory, may consist of 32.31 soda + 28.3 muriatic Acid, or, according to the new view, of 24.244 sodium + 36.366 chlorine, equivalent to 37.376 muriatic Acid. Admitting, then, the data to be correct, the composition of muriatic Acid of different densities will require the numbers to be altered, to suit the views of those who embrace the new doctrine respecting chlorine. This may be done by the rule of proportion; for as 87.376 is to 28.3, so is any number below 28.3 in the Table to the number required.

"Gay Lussac's Table, which is more copious, but in which the numbers are not reduced to a mean of the Barometer and Thermometer, is copied into Thomson's *Annals*, vol. ix. p. 18. A Table, by Professor Minecke of Halle, is inserted in the *Journal of Science*, vol. iii. p. 415. Dr. Thomson's elaborate Paper on this subject is printed in the XVth Volume of *Annals of Philosophy*; and Berzelius and Dulong's in the XVth Volume of *Ann. de Ch. et Ph.*"

TABLE \*IV.

*Table of the Quantity of Oil of Vitriol (Specific Gravity 18.8485) and of dry Sulphuric Acid in 100 parts by weight of diluted Acid at different densities.*  
By Dr. Ure, Brande's Journal, vol. iv. p. 122.

Liquid.	Sp. Gr.	Dry.	Liquid.	Sp. Gr.	Dry.
100	1.8485	81.54	50	1.3884	40.77
99	1.8475	80.72	49	1.3788	39.95
98	1.8460	79.90	48	1.3697	39.14
97	1.8439	79.09	47	1.3612	38.32
96	1.8410	78.28	46	1.3530	37.51
95	1.8376	77.46	45	1.3440	36.69
94	1.8336	76.65	44	1.3345	35.88
93	1.8290	75.83	43	1.3255	35.06
92	1.8233	75.02	42	1.3165	34.25
91	1.8179	74.20	41	1.3080	33.43
90	1.8115	73.39	40	1.2999	32.61
89	1.8043	72.57	39	1.2913	31.80
88	1.7962	71.75	38	1.2826	30.98
87	1.7870	70.94	37	1.2740	30.17
86	1.7774	70.12	36	1.2654	29.35
85	1.7673	69.31	35	1.2572	28.54
84	1.7570	68.49	34	1.2490	27.72
83	1.7465	67.68	33	1.2409	26.91
82	1.7360	66.86	32	1.2334	26.09
81	1.7245	66.05	31	1.2260	25.28
80	1.7120	65.23	30	1.2184	24.46
79	1.6993	64.42	29	1.2108	23.65
78	1.6870	63.60	28	1.2032	22.83
77	1.6750	62.78	27	1.1956	22.01
76	1.6630	61.97	26	1.1876	21.20
75	1.6520	61.15	25	1.1792	20.38
74	1.6415	60.34	24	1.1706	19.57
73	1.6321	59.52	23	1.1626	18.75
72	1.6204	58.71	22	1.1549	17.94
71	1.6090	57.89	21	1.1480	17.12
70	1.5975	57.08	20	1.1410	16.31
69	1.5868	56.26	19	1.1330	15.49
68	1.5760	55.45	18	1.1246	14.68
67	1.5648	54.63	17	1.1165	13.86
66	1.5503	53.82	16	1.1090	13.05
65	1.5390	53.00	15	1.1019	12.23
64	1.5280	52.13	14	1.0953	11.41
63	1.5170	51.37	13	1.0887	10.60
62	1.5066	50.55	12	1.0809	9.78
61	1.4960	49.74	11	1.0743	8.97
60	1.4860	48.92	10	1.0682	8.15
59	1.4760	48.11	9	1.0614	7.34
58	1.4660	47.29	8	1.0544	6.52
57	1.4560	46.48	7	1.0477	5.71
56	1.4460	45.66	6	1.0405	4.89
55	1.4360	44.85	5	1.0336	4.08
54	1.4265	44.03	4	1.0268	3.26
53	1.4170	43.22	3	1.0206	2.446
52	1.4073	42.40	2	1.0140	1.63
51	1.3977	41.58	1	1.0740	0.8154

TABLE IV.

*Mr. Dalton's Table of the Quantity of real Acid in 100 parts of liquid Sulphuric Acid; at the temperature of 60° Fahrenheit.*

Atoms of Acid+Water.	Real Acid per cent. by weight.	Real Acid per cent. by measure.	Specific Gravity.	Boiling Point.
1 + 0	100	Unknown.	Unknown.	Unknown.
1 + 1	81	150	1.850	620°
	80	148	1.849	605
	79	146	1.848	590
	78	144	1.847	575
	77	142	1.845	560
	76	140	1.842	545
	75	138	1.838	530
	74	135	1.833	515
	73	133	1.827	501
	72	131	1.819	487
	71	129	1.810	473
	70	126	1.801	460
	69	124	1.791	447
1 + 2	68	121	1.780	435
	67	118	1.769	422
	66	116	1.757	410
	65	113	1.744	400
	64	111	1.730	391
	63	108	1.715	382
	62	105	1.699	374
	61	103	1.684	367
	60	100	1.670	360
1 + 3	58.6	97	1.650	350
	50	76	1.520	290
	40	56	1.408	260
1 + 10	30	39	1.30+	240
1 + 17	20	24	1.200	224
1 + 38	10	11	1.10-	218

TABLE V.

*Table of the Precipitates produced by Solutions of the Hydrosulphates of Potassa, Soda, and Ammonia with different Saline Solutions.* Pelletan, Dict. de Chimie.

Salts.	Colour of Precipitate.	Nature of Precipitate.
Of Zircon	White	Zirconia.
Of Alumina	Ditto	Alumina.
Of Glycine and Yttria	No precip	—
Of all the 11d Class	Ditto	—
Of Manganese	Dirty white	A hydrosulphate or a sulphuretted hydrosulphate.
Of Zinc	White	A hydrosulphate
Of Iron	Black	A hydrosulphate or a sulphuretted hydrosulphate.
Of Antimony	Orange	Ditto
Of Protox of Tin	Chocolate	A hydrosulphate
Of Deutox. of Tin	Yellow	Ditto.
Of Cadmium	Ditto	A sulphuret.
Of Arsenic	Ditto	Ditto.
Of Molybdenum	Reddish brown	Ditto.
Of Chromium	Green	Ditto.
Of Columbium	Chocolate	Ditto.
Of Uranium	Brown	Ditto.
Of Cerium	Ditto	Ditto.
Of Cobalt	Black	Ditto.
Of Titanium	Bottle-green	Ditto.
Of Bismuth	Black	Ditto.
Of Copper	Ditto	Ditto.
Of Tellurium	Ditto	Ditto.
Of Nickel	Ditto	Ditto.
Of Lead	Ditto	Ditto.
Of Mercury	Black brown	Ditto.
Of Silver	Black	Ditto.
Of Palladium	Ditto	Ditto.
Of Platinum	Ditto	Ditto.
Of Gold	Ditto	Ditto.

TABLE VI.

*Table of the real or dry Nitric Acid in 100 parts of the liquid Acid at successive Specific Gravities, by Dr. Ure, Quarterly Journal, vol. iv. p. 297. (See Art. 446.)*

Sp. Grav.	Acid in 100.	Sp. Grav.	Acid in 100.	Sp. Grav.	Acid in 100.
1.5000	79.700	1.3783	52.602	1.1833	25.504
1.4980	78.903	1.3732	51.805	1.1770	24.707
1.4960	78.106	1.3681	51.068	1.1709	23.910
1.4940	77.309	1.3630	50.211	1.1648	23.113
1.4910	76.512	1.3579	49.414	1.1587	22.316
1.4880	75.715	1.3529	48.617	1.1526	21.519
1.4850	74.918	1.3477	47.820	1.1465	20.722
1.4820	74.121	1.3427	47.023	1.1403	19.925
1.4790	73.324	1.3376	46.226	1.1345	19.128
1.4760	72.527	1.3323	45.429	1.1286	18.331
1.4730	71.730	1.3270	44.632	1.1227	17.534
1.4700	70.933	1.3216	43.835	1.1168	16.737
1.4670	70.136	1.3163	43.038	1.1109	15.940
1.4640	69.339	1.3110	42.241	1.1051	15.143
1.4600	68.542	1.3056	41.444	1.0993	14.346
1.4570	67.745	1.3001	40.647	1.0935	13.549
1.4530	66.948	1.2947	39.850	1.0878	12.752
1.4500	66.151	1.2887	39.053	1.0821	11.955
1.4460	65.354	1.2826	38.256	1.0764	11.158
1.4424	64.557	1.2765	37.459	1.0708	10.361
1.4385	63.760	1.2705	36.662	1.0651	9.564
1.4346	62.963	1.2644	35.865	1.0595	8.767
1.4306	62.166	1.2583	35.068	1.0540	7.970
1.4269	61.369	1.2523	34.271	1.0485	7.173
1.4228	60.572	1.2462	33.474	1.0430	6.376
1.4189	59.775	1.2402	32.677	1.0375	5.579
1.4147	58.978	1.2341	31.880	1.0320	4.782
1.4107	58.181	1.2277	31.083	1.0267	3.985
1.4065	57.384	1.2212	30.286	1.0212	3.188
1.4023	56.587	1.2148	29.489	1.0159	2.391
1.3978	55.790	1.2084	28.692	1.0106	1.594
1.3945	54.993	1.2019	27.895	1.0053	0.797
1.3882	54.196	1.1958	27.098		
1.3833	53.399	1.1895	26.301		

Note by Dr. Henry: "In this Table, the real Acid in nitric Acid of Specific Gravity 1.5, is rated at 4.8 per cent. more than is contained in it according to Dr. Wollaston and Mr. Phillips, the mean of whose numbers is 25.1 water + 74.9 Acid in 100 parts of Acid of that density. The numbers in the Table will, I believe, however, be very near the truth, if reduced at the rate of 6 per cent. Thus 6 per cent. on 79.7 is 4.782; and 79.7 - 4.782 = 74.918, which is very near the true number."

TABLE VII.

*Of the Specific Gravities of certain Atomic Combinations of Nitric Acid and Water, by Dr. Thomson, First Principles, vol. i. p. 114. (See Art. 446.)*

Atoms of Acid	Atoms of Water	Acid in 100.	Specific Gravity.
1	1	85.714	1.55
1	2	75.000	1.4855
1	3	66.668	1.4546
1	4	60.000	1.4237
1	5	54.545	1.3928
1	6	50.000	1.3692
1	7	46.260	1.3456
1	8	42.857	1.3220
1	9	40.000	1.3032
1	10	37.500	1.2844
1	11	35.294	1.2656
1	12	32.574	1.2495
1	13	31.579	1.2334
1	14	30.000	1.2173
1	15	28.571	1.2012

TABLE VIII.

*Table exhibiting the Proportion, by Volume, of Aqueous Vapour existing in any Gas in contact with Water at the corresponding Temperatures, and at the mean Barometric Pressure of 30 Inches.*

40° ....	.00933	61° ....	.01923
41° ....	.00973	62° ....	.01980
42° ....	.01013	63° ....	.02050
43° ....	.01053	64° ....	.02120
44° ....	.01093	65° ....	.02190
45° ....	.01133	66° ....	.02260
46° ....	.01173	67° ....	.02330
47° ....	.01213	68° ....	.02406
48° ....	.01253	69° ....	.02483
49° ....	.01293	70° ....	.02566
50° ....	.01333	71° ....	.02653
51° ....	.01380	72° ....	.02740
52° ....	.01426	73° ....	.02830
53° ....	.01480	74° ....	.02923
54° ....	.01533	75° ....	.03020
55° ....	.01586	76° ....	.03120
56° ....	.01640	77° ....	.03220
57° ....	.01693	78° ....	.03323
58° ....	.01753	79° ....	.03423
59° ....	.01810	80° ....	.03533
60° ....	.01866		





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Part V.

## TABLE XI.

*Table of the Properties of the Metals.*

Name.	When discovered.	By whom.	Colour.	Specific Gravity.	Fusing point, Fahrenheit.	Scale of ductility.	Scale of malleability.	Tenacity.	Ratio of hardness.
Gold.....	Known from the earliest ages.	....	Pure yellow.	19.257	5237	1	1	68.216	8
Silver.....		....	White.	10.474	3677	2	2	85.062	6
Iron.....		....	Blue-grey.	7.788	17977	4	8	269.659	3
Copper.....		....	Red.	8.895	4587	5	3	157.399	5
Mercury....		....	White.	13.568	—39	..	..	....	None.
Lead.....	XVth Cent.	....	Blue.	11.352	594	8	6	....	14
Tin.....		....	White.	7.291	442	7	4	24.200	12
Zinc.....		Paracelsus.	Bluish-white.	6.661	700	6	7	12.720	9
Bismuth....		Agricola.	Yellowish-white.	9.822	476	..	..	....	7
Antimony...		B. Valent.	Bluish-white.	6.702	932	..	..	....	10
Arsenic.....	1723	Braut.	Grey.	8.308	...	..	..	....	13
Cobalt.....	..	Ditto	Grey-white.	8.538	16677	..	..	....	11.
Platinum....	1741	Wood	Bluish-white.	21.500	G. B. P.	3	5	124.000	4
Nickel.....	1751	Cronstedt.	White.	8.279	21877	9	9	....	..
Manganese..	1774	Scheele.	Grey-white.	5.850	Ditto.	..	..	....	2
Tungsten...	1781	D'Elhuyart.	....	17.600	G. B. P.	..	..	....	1
Tellurium...	1782	Muller.	....	6.115	....	..	..	....	..
Molybdenum.	Ditto.	Hjelm.	Grey.	7.400	G. B. P.	..	..	....	..
Titanium....	1781	Gregor.	Red.	....	Ditto.	..	..	....	..
Uranium....	1789	Klaproth.	Grey.	9.000	Ditto.	..	..	....	..
Chromium...	1797	Vauquelin.	....	....	Ditto.	..	..	....	..
Columbium..	1802	Hatchett.	....	....	Ditto.	..	..	....	..
Palladium...	1803	Wollaston.	Bluish-white.	11.300	....	10	10	....	1
Rhodium....	Ditto.	Ditto.	Greyish-white.	....	G. B. P.	..	..	....	..
Iridium.....	Ditto.	Descotils.	....	....	Ditto.	..	..	....	..
Osmium.....	Ditto.	Tenant.	Bluish-black.	....	....	..	..	....	..
Cerium.....	1804	Berzelius.	Grey-white.	....	G. B. P.	..	..	....	..
Potassium..	1807	Davy.	Ditto.	0.865	136	..	..	....	100
Sodium.....			Ditto.	0.972	194	..	..	....	100
Barium.....			....	....	....	..	..	....	..
Strontium...			....	....	....	..	..	....	..
Calcium....			....	....	....	..	..	....	..
Cadmium...	1818	Stromeyer.	White	8.604	....	11	11	....	..
Lithium....	1818	Arfvedson.	....	....	....	..	..	....	..

TABLE XII. THE ATOMIC WEIGHTS, CONSTITUTIONS, &amp;c. OF BODIES.

The following Table serves partly as a reference by which to find any substance mentioned in this Treatise. In thus employing it, the reader will be immediately struck with the very general and limited nature of the description of each individual substance, which it is possible to convey in a Treatise of this extent; but with this unavoidable disadvantage, the unity of method is preserved, and the outline of a plan for what may be enlarged by any one into a more ample Treatise is developed. The Table is also designed to show the state of our knowledge with regard to the combining proportions, or our belief respecting the atomic constitution of substances. The nomenclature made use of has been already explained in Art. (110.), (111.), and (112.) It possesses the following advantages. In Oxides, Iodides, Chlorides, Sulphurets, Salts, &c. it invariably employs such a name as will point out at once the degree of oxidation, &c. In all Salts it points out with precision the atomic proportion between the Acid and the base; and also the degree of oxygenation of the base. The Greek prefixes Prot-, Deut-, Trit-, Tetart-, &c. are solely confined to the degree of oxygenation; while in the Iodides, Sulphurets, &c. bi-, ter-, quater-, &c. are employed as in the case of Salts stated in the Paradigma. (111.) The practical necessity for this will be found by any one who shall try to interchange these two terms; and it is from such compulsion that we depart from our original design mentioned in (111.), of applying these Greek terms to the Chlorides, Sulphurets, &c. Our nomenclature does not, however, extend to a description of the water in each Salt.

It may be objected that these descriptive names are inconveniently long; let us, therefore, fairly examine one or two of the longest names in the following Table, and inquire whether the advantage of a true atomic description is not sufficient to justify the change. The following, for example, is the strongest case that could be proposed against us. Persesquisulphate of iron is called Hemi-deuto-semi-bisulphate of Iron. The word Persesquisulphate implies that the Salt contains the Peroxide of Iron, out then we know not the proportion between the atoms of Iron and of Oxygen. By Sesqui we learn conventionally that there is base one atom + Acid  $1\frac{1}{2}$  atom, or, perhaps, only that there is half as much more Acid in this Salt as in the Sulphate. The name we employ tells us more. As an *invariable rule* we take the Greek commencement of the name *Hemi-deuto*, from this we learn that the oxide contains Oxygen  $1\frac{1}{2}$  atom + metal 1 atom. From the next portion *semi-bi* we learn that the Salt contains Acid  $1\frac{1}{2}$  atom + base 1 atom, and from the remainder of the word the nature of the Acid and of the base are obvious.

Deuto-semi-bisulphate of Uranium may be similarly analyzed, and will be found equally explanatory; while Sulphate of Uranium, the common name, neither expresses the degree of oxidation of the Metal, nor the atomic constitution of the Salt.

The less important classes of Salts are not given at length for want of space. A valuable Table of Double Salts given in Thomson's *First Principles* is omitted for the same reason.

The main authority admitted for the following Table is *The First Principles* of Dr. Thomson: this Work has been employed wherever it was available. It was at first designed to cite the exact authority for every number here inserted, but here also our unavoidable limits of space have checked us. Hydrogen is the unit to which all other atomic weights are referred; but should any one prefer the oxygen scale, it is easy to divide all the numbers by 8. In the column headed State, S means solid. L, Liquid. G, a Gas. V, vapour. C, crystallized. H, hydraous. A, anhydrous.

Substance.	State.	Elements.	No. of Atoms.	Constituent Proportions by Weight.	Total Weight of Atoms referred to Hyd.	Article in this Treatise.	Substance.	State.	Elements.	No. of Atoms.	Constituent Proportions by Weight.	Total Weight of Atoms referred to Hyd.	Article in this Treatise.
<b>Acetates</b>							<b>Potassa, Proto-bisacet. of.</b>	C.&H.	Acetic Acid Protox. Potassium Water	2 1 6	100 48 54	202	(634)
Alumina, Acetate of.....	C.&H.	Acetic Acid Alumina Water	1 1 1	50 18 9	77	(539)	Silver, Protoacetate of....	C.&H.	Acetic Acid Protox. Silver	1 1	50 118	168	(914)
Ammonia, Acetate of....	C.&H.	Acetic Acid Ammonia Water	1 1 7	50 17 63	130	(469)	Soda, Protoacetate of....	C.&H.	Acetic Acid Protox. Sodium Water	1 1 6	50 42 54	136	(634)
Baryta, Acetate of.....	C.&H.	Acetic Acid Baryta Water	1 1 3	50 78 27	155	(584)	Strontia, Protoacetate of..	C.&H.	Acetic Acid Strontia Water	1 1 1	50 59 9	111	(571)
Cadmium, Protoacetate of.	C.&H.	Acetic Acid Protox. Cadm. Water	1 1 2	50 64 18	132	(658)	Zinc, Protoacetate of....	C.&H.	Acetic Acid Protox. Zinc Water	1 1 7	50 50 63	163	(691)
Copper, Protoacetate of....	C.&H.	Acetic Acid Prot. Cop. (black) Water	1 1 1	50 40 9	99	(831)	Acetous Fermentation.....						(1063)
Ditto, Proto-semi-diacetate of (Sesquisulphate)....	C.&H.	Acetic Acid Protox. Cop. Water	1 1 3	50 60 27	137	(Do.)	<b>Acids.</b>						
Ditto, Proto-diacetate of	C.&H.	Acetic Acid Protox. Cop. Water	1 2 6	50 80 54	184	(Do.)	Acetic.....	A.	Oxygen Hydrogen Carbon	3 2 4	24 2 24	50	(978)
Ditto, Proto-triacetate of	C.&H.	Acetic Acid Protox. Cop. Water	1 3 2	50 120 18	188	(Do.)	Ditto.....	C.&H.	Acetic Acid Water	1 1	50 9	59	(Do.)
Iron, Protoacetate of.....	C.&H.	Acetic Acid Protox. Iron Water	1 1 3	50 35 27	113	(657)	Amniotic.....						(1076)
Lead, Protoacetate of....	C.&H.	Acetic Acid Protox. Lead Water	1 1 3	50 112 27	189	(861)	Antimonious (see Hemi-deutoxide of A.).....						(765)
Ditto, Proto-diacetate of....	C.&H.	Acetic Acid Protox. Lead Water	1 2 2	50 224 27	361	(Do.)	Antimonic (see Deutoxide of A.).....						(768)
Ditto, Proto-triacetate of....	C.&H.	Acetic Acid Protox. Lead Water	1 3 2	50 336 18	404	(Do.)	Arsenious (see Deutoxide of A.).....						(709)
Lime, Acetate of.....	C.&H.	Acetic Acid Lime Water	1 1 6	50 28 54	132	(559)	Benzoin (Flowers of Benjamin).....						(708)
Magnesia, Acetate of.....	C.&H.	Acetic Acid Magnesia Water	1 1 5	50 20 45	115	(536)	Oxygen.....			3	24		
Manganese, Protoacetate of (Acetate T.).....	C.&H.	Acetic Acid Protox. Mang. Water	1 1 4	50 80 36	162	(645)	Hydrogen.....			2	2		
Mercury, Protoacetate.....	C.&H.	Acetic Acid Protox. Merc. Water	1 1 4	50 208 36	294	(879)	Carbon.....			15	90	120	(981)
Nickel, Protoacetate of....	C.&H.	Acetic Acid Protox. Nickel Water	1 1 5	50 34 45	139	(892)	Chlorine.....			2	16		
Potassa, Protoacetate of....	C.&H.	Acetic Acid Protox. Potassium Water	1 1 2	50 48 18	116	(634)	Boron.....			1	24	40	(335)
							Ditto.....	C.&H.	Acetic Acid Water Fluorine Borax	1 1 2 2	40 18 18 16	58	(Do.)
							Boro-fluoric.....						(194)
							Camphoric.....						(897)
							Carbolic.....	G.	Oxygen Carbon	2 1	16 6	22	(312)
							Chloric.....			5	40		
							Chloridic.....			1	36	76	(147)
							Chloro-cyanic.....			2	72	196	(399)
							Chloro-carbonic.....			9	96	62	(475)
							Chromic (see Tritox. of Chrom.).....			1	36		
							Citric.....	A.	Hydrogen Carbon Oxygen	2 4 4	2 24 32	58	(882)

TABLE XII. *continued.*[illegible]

TABLE XII. *continued.*

Substance.	State.	Elements.	No. of Atoms	Constituent Proportions by Weight	Total Weight of Atoms referred to Hyd.	Article in this Treatise.	Substance.	State.	Elements.	No. of Atoms	Constituent Proportions by Weight	Total Weight of Atoms referred to Hyd.	Article in this Treatise.
Strontian, Arseniate of ..	..	Arsenic Acid .. Strontian .. Water ..	1 1 8	69 52 72	186		Lime, Carbonate of .....	A.	Carbonic Acid .. Lime ..	1 1	29 36	50	
Silver, Prot-hemi-diarseni. of (Subsesquarson. T.)	A.	Arsenic Acid .. Protox. Silver ..	1 1½	69 177	239		Magnesia, Carbonate of ..	S.	Carbonic Acid .. Magnesia .. Water ..	1 1 3	29 36 37	69	
Zinc, Prot-arseniate of ..	..	Arsenic Acid .. Protox. Zinc .. Water ..	1 1 8	69 42 72	176		Ditto, Ditto .....	A.	Carbonic Acid .. Magnesia ..	1 1	29 36	42	
<i>Arsenites</i>							Manganese, Proto-carbonate of ..	S.	Carbonic Acid .. Protox. Mang. .. Water ..	1 1 2	29 36 18	76	
Lime, Arsenite of .....	A.	Arsenious Acid .. Lime ..	1 1	54 54	82 (708)		Mercury, Prot-hemibicarbon- ate of (Sesquicarbon- ate)	A.	Carbonic Acid .. Protox. Merc. ..	1½ 1	83 968	941	
Potassa, Arsenite of .....	..	Arsenious Acid .. Potassa ..	1 1	54 54	102		Nickel, Proto-carbonate of	S.	Carbonic Acid .. Protox. Nickel .. Water ..	1 1 3	29 34 37	83	
Silver, Arsenite of .....	..	Arsenious Acid .. Protox. Silver ..	1 1	118 54	172		Potassa, Carbonate of .....	C.	Carbonic Acid .. Potassa .. Water ..	1 1 2	29 48 18	86	
Soda, Arsenite of .....	..	Arsenious Acid .. Soda ..	1 1	54 33	86		Ditto, Prot-hemi-bicarbon- ate of (Sesquicarbon- ate)	C.	Carbonic Acid .. Potassa .. Water ..	1½ 1 6	33 48 54	135	
Asparagin .....	..	..	..	..	(1029)		Potassium, Proto bicarbon- ate of .....	C.	Carbonic Acid .. Potassa .. Water ..	2 1 1	44 48 9	101	
Atropin .....	..	..	..	..	(1013)		Silver, Proto-carbonate of ..	..	Carbonic Acid .. Protox. Silver ..	1 1	22 118	140	
Balsam .....	..	..	..	..	(1019)		Sodium, Proto-carbonate of	C.	Carbonic Acid .. Soda .. Water ..	1 1 10	22 32 90	144	
Barym .....	S.	..	..	..	(574)		Ditto, Prot-hemi-bicarbon- ate of (Sesquicarbon- ate)	C.	Carbonic Acid .. Soda .. Water ..	1½ 1 2	33 32 44	85	
Baryta (see Protoxide of Baryum.)	..	..	..	..	(575)		Ditto, Bicarbonate of .....	C.	Carbonic Acid .. Soda .. Water ..	1½ 1 1	33 32 9	74	
Benzoates					(941)		Strontia, Proto-carbonate of ..	A.	Carbonic Acid .. Strontia ..	1 1	29 52	74	
Ammonia, Benzoate of .....	S.	Benzoic Acid .. Ammonia .. Water ..	1 1 1	120 17 9	146		Uranium, Deuto-carbonate of ..	..	Carbonic Acid .. Deutox. Uran. .. Water ..	1 1 1	22 234 9	255	
Potassa, Benzoate of .....	..	Benzoic Acid .. Potassa .. Water ..	1 1 3	120 48 37	195		Yttrium, Proto-carbonate of ..	..	Carbonic Acid .. Yttria .. Water ..	1 1 1	22 42 9	73	
Lead, Proto-benzoate of ..	..	Benzoic Acid .. Protox. Lead .. Water ..	1 1 1	120 112 9	241		Zinc, Proto-carbonate of ..	C.	Carbonic Acid .. Protox. Zinc .. Water ..	1 1 1	22 42 9	73	
Bassorin .....	..	..	..	..	(1042)		Ditto, Ditto .....	A.	Carbonic Acid .. Protox. Zinc ..	1 1	22 42	64	
Bile .....	..	..	..	..	(1091)		Caftarin .....	..	..	..	..	(1044)	
Biliary Calculi .....	..	..	..	..	(1114)		Carmin .....	..	..	..	..	(1087)	
Bismuth .....	S.	..	..	..	(810)		Carthamin .....	..	..	..	..	(1034)	
Bitumens .....	..	..	..	..	(1025)		Cerebral substance .....	..	..	..	..	(1008)	
Blood .....	..	..	..	..	(1094)		Cerine .....	..	..	..	..	(1045)	
<i>Borates</i>					(341)		Cerium .....	S.	..	..	..	62 (77)	
Ammonia, Borate of .....	C.	Boric Acid .. Ammonia .. Water ..	1 1 2	24 17 18	59		Charcoal .....	S.	..	..	..	(237)	
Baryta, Biborate of .....	A.	Boric Acid .. Baryta ..	2 1	48 54	126		Chesse .....	..	..	..	..	(1008)	
Magnesia, Biborate of .....	A.	Boric Acid .. Magnesia ..	2 1	48 20	68		<i>Chlorates</i>						
Soda, Biborate of (Borax)	C.	Boric Acid .. Soda .. Water ..	2 1 8	48 32 72	152		Barym, Proto chlorate of ..	A.	Chloric Acid .. Baryta ..	1 1	76 78	151	
Borax .....	S.	..	..	..	8 (324)		Lead, Proto chlorate of ..	A.	Chloric Acid .. Protox. Lead ..	1 1	76 112	188	
Brucea .....	..	..	..	..	(1008)		Mercury, Proto-chlorate of	A.	Chloric Acid .. Protox. Merc. ..	1 1	76 908	234	
Bryonine .....	..	..	..	..	(1043)		Potassium, Proto-chlorate of ..	A.	Chloric Acid .. Potassa ..	1 1	76 48	124	
Cadmium .....	S.	..	..	..	56 (64)		<i>Chlorides</i>						
Caffein .....	S.	..	..	..	(1039)		Antimony, Chloride of .....	..	Chlorine .. Antimony ..	1 1	36 44	80	
Calcium .....	..	..	..	..	20 (341)		Ditto, Dichloride of .....	..	Chlorine .. Antimony ..	1 2	36 88	124	
Calomel (see Chloride of Mercury)	..	..	..	..	(1114)		Baryum, Chloride of .....	..	Chlorine .. Baryum ..	1 1	36 70	106	
Camphor .....	..	..	..	..	(874)		Bismuth, Chloride of .....	..	Chlorine .. Bismuth ..	1 1	36 78	108	
Caoutchouc .....	..	..	..	..	(1022)		Cadmium, Chloride of .....	..	Chlorine .. Cadmium ..	1 1	36 56	92	
Carbon .....	S.	..	..	..	(1020)		Cerium, Chloride of .....	..	Chlorine .. Cerium ..	1 1	36 50	86	
<i>Carbonates</i>					(237)		Chromium, Chloride of .....	..	Chlorine .. Chromium ..	1 1	36 38	64	
Ammonia, Carbonate of ..	S. & A.	Carbonic Acid .. Ammonia ..	1 1	22 17	39		Cobalt, Chloride of .....	..	Chlorine .. Cobalt ..	1 1	36 58	69	
Ditto, Hemi bicarbonate of	S.	Carbonic Acid .. Ammonia .. Water ..	1½ 1 1	33 17 9	59								
Ammonia, Bicarbonate of ..	S.	Carbonic Acid .. Ammonia .. Water ..	2 1 1	44 17 9	70								
Baryta, Carbonate of .....	S. & A.	Carbonic Acid .. Baryta ..	1 1	22 78	100								
Bismuth, Proto-tricarbon- ate of .....	S.	Carbonic Acid .. Protox. Bism. .. Water ..	1 2 2	22 80 18	120								
Cadmium, Carbonate of .....	S. & A.	Carbonic Acid .. Protox. Cadm. ..	1 1	22 64	86								
Cobalt, Carbonate of .....	S.	Carbonic Acid .. Protox. Cobalt .. Water ..	1 1 1	22 34 9	66								
Copper, Proto-dicarbon- ate of .....	S.	Carbonic Acid .. Protox. Copper .. Water ..	1 2 1	22 40 9	111								
Ditto, Ditto .....	A.	Carbonic Acid .. Protox. Copper ..	1 2	22 80	102								
Iron, Proto-carbonate of ..	A.	Carbonic Acid .. Protox. Iron ..	1 1	22 36	58								
Lead, Proto-carbonate of ..	A.	Carbonic Acid .. Protox. Lead ..	1 1	22 112	134								

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**\*5 F 2**

TABLE XII. continued.

Substances.	State.	Elements.	No. of Atoms.	Constituent Proportions by Weight.	Total Weight of Atoms referred to Hyd.	Article in this Table.	Substances.	State.	Elements.	No. of Atoms.	Constituent Proportions by Weight.	Total Weight of Atoms referred to Hyd.	Article in this Table.
Cadmium, H. of .....	C.	Hydrochloric Acid	1	37	110		Malates .....	..	..	..	..	28	(979)
		Oxide of Cadm.	1	64			Manganese .....	..	..	..	..	..	(687)
		Water .....	1	9			Margarates .....	..	..	..	..	..	(1084)
Cerium, H. of .....	C.	Hydrochloric Acid	1	97	154		Mercurates .....	..	..	..	..	900	(980)
		Oxide of Cerium	1	98			Mercury .....	..	..	..	..	..	(870)
		Water .....	1	9			Molybdates .....	..	..	..	..	..	(781)
Chromium, H. of .....	C.	Hydrochloric Acid	1	37	107		Molybdenum .....	..	..	..	..	48	(710)
		Oxide of Chrom.	1	36			Mucosylates .....	..	..	..	..	..	(991)
		Water .....	9	81			Morphia .....	..	..	..	..	..	(1008)
Cobalt, Prot. H. of .....	C.	Hydrochloric Acid	1	37	95		Mucilage .....	..	..	..	..	..	(1031)
		Prot. Cobalt ..	1	34			Mucates .....	..	..	..	..	..	(998)
		Water .....	4	36			Mucus .....	..	..	..	..	..	(1110)
Copper, Prot. H. of .....	C.	Hydrochloric Acid	1	37	100		Muriates (see Hydrochlorates) ..	..	..	..	..	..	(159)
		Prot. Copper ..	1	40			Muriatic Acid (see Hydrochloric A.) ..	..	..	..	..	..	(149)
		Water .....	2	18			Nails .....	..	..	..	..	..	(1169)
Glycyra, H. of .....	C.	Hydrochloric Acid	1	37	?		Nanoic Acid .....	..	..	..	..	..	(999)
		Glycyra .....	1	26			Naphtha .....	..	..	..	..	..	(1025)
		Water .....	1	9			Natron (see Carb. Soda) ..	..	..	..	..	..	(605)
Iron, Prot. H. of .....	C.	Hydrochloric Acid	1	37	100		Nickel .....	..	..	..	..	36	(883)
		Prot. Iron .....	1	26			Nitrates .....	..	..	..	..	..	(458)
		Water .....	3	27			Alumina, Dinitrate of ..	..	Nitric Acid .....	1	54	180	
Lime, H. of .....	C.	Hydrochloric Acid	1	37	119			Alumina .....	2	36			
		Lime .....	1	28				Water .....	10	90			
Lithia, H. of .....	C.	Hydrochloric Acid	1	37	119			Nitric Acid .....	1	54	162		
		Lithia .....	1	18				Alumina .....	3	54			
		Water .....	6	54				Water .....	6	54			
Magnesia, H. of .....	C.	Hydrochloric Acid	1	37	116		Ammonia, Nitrate of .....	..	Nitric Acid .....	1	54	80	
		Magnesia .....	1	24				Ammonia .....	1	17			
		Water .....	5	45			Baryta, Nitrate of .....	..	Nitric Acid .....	1	54	132	
Manganese, Prot. H. of ..	C.	Hydrochloric Acid	1	37	109			Baryta .....	1	78			
		Prot. Mang. ..	1	36			Bismuth, Proto-nitrate of ..	..	Nitric Acid .....	1	54	161	
		Water .....	4	36				Protox. Bism.	1	54			
Nickel, Prot. H. of .....	C.	Hydrochloric Acid	1	37	116		Ditto, Proto-dinitrate of ..	..	Nitric Acid .....	1	54	232	
		Prot. Nickel ..	1	34				Protox. Bism.	2	108			
		Water .....	5	45			Cadmium, Nitrate of .....	..	Nitric Acid .....	1	54	154	
Strontia, H. of .....	C.	Hydrochloric Acid	1	37	130			Oxide of .....	4	30			
		Strontia .....	1	52			Cobalt, Proto-nitrate of ..	..	Nitric Acid .....	1	54	142	
		Water .....	8	72				Protox. Cobalt ..	6	54			
Tin, Deuto-bihydrochl. of (Bismutate of Tin) ....	C.	Hydrochloric Acid	2	74	175		Copper, Proto-nitrate of ..	..	Nitric Acid .....	1	54	157	
		Dextox. of Tin	1	71				Protox. Copper ..	7	63			
		Water .....	3	27			Iron, Proto-nitrate of .....	..	Nitric Acid .....	1	54	153	
Zinc, Prot. Hydrochl. of ..	A.	Hydrochloric Acid	1	37	79			Protox. Iron .....	7	63			
		Prot. Tin .....	1	42			Ditto, Hemideuto semi bi-nitrate of (Persulphate) ..	..	Nitric Acid .....	14	81	193	
Zirconia, Hyd. of .....	C.	Hydrochloric Acid	1	37	130			Hemideutox. Iron	8	72			
		Zirconia .....	1	48			Lead, Proto-nitrate of ..	C & A	Nitric Acid .....	1	54	166	
		Water .....	5	45				Protox. Lead .....	1	112			
Hydrocyanates .....	..	..	..	..	..	(474)	Lime, Nitrate of .....	C.	Nitric Acid .....	1	54	136	
Hydrofluates .....	..	..	..	..	..	(176)		Lime .....	1	24			
Hydrogen .....	G.	..	..	..	1	(283)	Magnesia, Nitrate of .....	C.	Nitric Acid .....	1	54	192	
Hydrogurets (Hydurets) ..	..	..	..	..	..	(283)		Magnesia .....	6	54			
Carbon, Hydrogurets of, see Art (312) .....	..	..	..	..	..	(312)	Manganese, Proto-nitrate of ..	..	Nitric Acid .....	1	54	153	
Phosphorus, Hydroguret of ..	..	Hydrogen .....	1	12	13			Protox. Mang. ..	7	63			
Ditto, Bihydroguret of ..	..	Hydrogen .....	2	24	14		Mercury, Proto-nitrate of ..	..	Nitric Acid .....	1	54	280	
		Phosphorus ..	1	12				Protox. Merc. ..	1	208			
Hyduret of Sulphur (see Hydro-sulphurous Acid) ..	..	..	..	..	..	(403)	Ditto, Deuto-nitrate of (Per-nitrate) ..	A.	Nitric Acid .....	1	54	270	
Hydro-sulphates .....	..	..	..	..	..	(407)		Deutox. Merc. ..	1	516			
Hypophosphites .....	..	..	..	..	..	(394)	Nickel, Proto-nitrate of .....	..	Nitric Acid .....	1	54	133	
Hyposulphates .....	..	..	..	..	..	(390)		Protox. Nick. ..	1	34			
Hyposulphites .....	..	..	..	..	..	(388)	Potassa, Nitrate of (Nitre) ..	A.	Nitric Acid .....	1	54	109	
Ignesceates .....	..	..	..	..	..	(986)		Potassa .....	1	48			
Indigo .....	..	..	..	..	..	(1045)	Silver, Proto-nitrate of .....	A.	Nitric Acid .....	1	54	179	
Inuline .....	..	..	..	..	..	(1052)		Protox. Silver ..	1	54			
Iodates .....	S.	..	..	..	124	(207)	Soda, Nitrate of .....	A.	Nitric Acid .....	1	54	86	
Iodides (Iodures) .....	..	..	..	..	..	(907)	Strontia, Nitrate of .....	..	Nitric Acid .....	1	54		
Iridium .....	..	..	..	..	30	(964)		Strontia .....	1	39			
Iron .....	..	..	..	..	28	(645)	Ditto, Ditto .....	A.	Nitric Acid .....	1	54	106	
Ittria (see Yttria) .....	..	..	..	..	..	(498)							
Jelly .....	..	..	..	..	..	(1049)							
Kinates .....	..	..	..	..	..	(987)							
Lac .....	S.	..	..	..	..	(989)							
Laccates .....	..	..	..	..	..	(988)							
Lead .....	S.	..	..	..	104	(945)							
Lime .....	S.	..	..	..	28	(551)							
Lithia .....	S.	..	..	..	18	(558)							
Lithium .....	S.	..	..	..	10	(567)							
Lymph .....	S.	..	..	..	..	(1108)							
Lupuline .....	S.	..	..	..	..	(1093)							
Magnesia .....	S.	..	..	..	20	(527)							
Magnesium .....	S.	..	..	..	12	(526)							



TABLE XII. *continued*

Substance.	State.	Elements.	No. of Atoms.	Constituent Proportions by Weight.	Total Weight of Atoms referred to Hyd.	Article in this Treatise.	Substance.	State.	Elements.	No. of Atoms.	Constituent Proportions by Weight.	Total Weight of Atoms referred to Hyd.	Article in this Treatise.
Uranium, Deuto-semi-nitrate of (Besquivaltrate).....	..	Nitric Acid..... Deutoz. of Uran..... Water.....	14 1 17	81 994 152	458	14	Copper, Protoxide of (Black Oxide).....	..	Oxygen..... Copper.....	1 1	8 28	40	(885)
Zinc, Proto-nitrate of.....	..	Nitric Acid..... Protoz. Zinc..... Water.....	1 1 6	54 42 84	150		Glycyneum, Protoxide of.....	..	Oxygen..... Glycyneum.....	1 1	8 18	26	(800)
Nitric Ether.....	L.	..	..	..	..	(1024)	Gold, Protoxide of.....	..	Oxygen..... Gold.....	1 1	8 200	208	(864)
Nitric Acid.....	..	..	..	..	..	(455)	Gold, Tritoxide of.....	..	Oxygen..... Gold.....	3 1	24 200	224	(Do.)
Nitrogen (Azote).....	G.	..	..	..	..	(445)	Iron, Protoxide of.....	..	Oxygen..... Iron.....	1 1	8 28	36	(858)
Nitrous Gas.....	G.	..	..	..	..	(445)	Ditto, Hemideutoxide of (Peroxide).....	..	Oxygen..... Iron.....	14 1	12 28	40	(Do.)
Nitrous Oxide.....	G.	..	..	..	..	(451)	Lead, Protoxide of.....	S.	Oxygen..... Lead.....	1 1	8 104	112	(848)
Oil.....	L.	..	..	..	..	(1015)	Ditto, Hemideutoxide of (Deutoxide of L.).....	S.	Oxygen..... Lead.....	14 1	12 104	116	(Do.)
Oleum Gas.....	G.	Carbon..... Hydrogen.....	2 2	12 2	14	(317)	Ditto, Deutoxide of (Peroxide of L.).....	S.	Oxygen..... Lead.....	2 1	16 104	120	(Do.)
Olivite.....	S.	..	..	..	..	(1055)	Lithium, Protoxide of (Lithia).....	S.	Oxygen..... Lithium.....	1 1	8 10	18	(588)
Osmium.....	S.	..	..	..	..	(895)	Magnesium, Oxide of (Magnesia).....	S.	Oxygen..... Magnesium.....	1 1	8 12	20	(527)
Oxalates.....	..	..	..	..	..	(980)	Manganese, Suboxide of.....	S.	Oxygen..... Manganese.....	1 2	8 56	64	(640)
Oxides.....	..	..	..	..	..	..	Ditto, Protoxide of (Oxide of M.).....	S.	Oxygen..... Manganese.....	1 1	8 28	36	(Do.)
Aluminium, Protox. of (Alumina).....	S.	Oxygen..... Aluminium.....	1 1	8 10	18	(514)	Ditto, Hemideutoxide of (Deutoxide of M.).....	S.	Oxygen..... Manganese.....	14 1	12 28	40	(Do.)
Antimony, Protox. of.....	..	Oxygen..... Antimony.....	1 1	8 44	52	(757)	Ditto, Deutoxide of (Tritoxide of M.).....	S.	Oxygen..... Manganese.....	2 1	16 28	44	(Do.)
Ditto, Hemideutoxide of (Deutoxide, or Antimonious Acid).....	..	Oxygen..... Antimony.....	14 1	12 44	56	(766)	Ditto, Tritoxide of (Manganese Acid).....	S.	Oxygen..... Manganese.....	3 1	24 28	52	(Do.)
Ditto, Deutoxide of Peroxide, or Antimonious A.....	..	Oxygen..... Antimony.....	2 1	16 44	60	(766)	Ditto, Tetartoxide of (Manganese Acid).....	S.	Oxygen..... Manganese.....	4 1	32 28	60	(Do.)
Arsenic, Deutoxide of (Arsenious Acid).....	..	Oxygen..... Arsenic.....	2 1	16 38	54	(708)	Mercury, Protoxide of.....	S.	Oxygen..... Mercury.....	1 1	8 200	208	(873)
Ditto, Tritoxide of (Arsenic Acid).....	..	Oxygen..... Arsenic.....	8 1	24 38	62	(709)	Ditto, Deutoxide of (Peroxide of M.).....	S.	Oxygen..... Mercury.....	2 1	16 200	216	(Do.)
Barium Protoxide of (Baryta).....	S.	Oxygen..... Barium.....	1 1	8 70	78	(575)	Molybdenum, Protoxide of.....	..	Oxygen..... Molybdenum.....	1 1	8 48	56	(713)
Ditto Deutoxide of.....	..	Oxygen..... Barium.....	2 1	16 70	86		Ditto, Deutoxide of (Molybdenous A.).....	..	Oxygen..... Molybdenum.....	2 1	16 48	64	(720)
Bismuth, Protoxide of.....	..	Oxygen..... Bismuth.....	1 1	8 72	80	(913)	Ditto, Tritoxide of (Molybdenous A.).....	..	Oxygen..... Molybdenum.....	3 1	24 48	72	(721)
Cadmium Protoxide of.....	..	Oxygen..... Cadmium.....	1 1	8 56	64	(647)	Nickel Protoxide of.....	..	Oxygen..... Nickel.....	1 1	8 26	34	(888)
Calcium, Protoxide of (Lime).....	..	Oxygen..... Calcium.....	1 1	8 20	28	(531)	Ditto, Hemideutoxide of.....	..	Oxygen..... Nickel.....	14 1	12 26	38	(Do.)
Carbon, Protoxide of (Carbonic Oxide).....	G.	Oxygen..... Carbon.....	1 1	8 6	14	(311)	Nitrogen, Protoxide of (Nitrous Oxide).....	G.	Oxygen..... Nitrogen.....	1 1	8 14	22	(461)
Ditto, Deutoxide of (Carbonic Acid).....	G.	Oxygen..... Carbon.....	2 1	16 6	22	(312)	Ditto, Deutoxide of (Nitric Oxide).....	G.	Oxygen..... Nitrogen.....	2 1	16 14	30	(455)
Cerium, Protoxide of.....	..	Oxygen..... Cerium.....	1 1	8 50	58	(740)	Ditto, Tritoxide of (Hypocitric Acid).....	G.	Oxygen..... Nitrogen.....	3 1	24 14	38	(466)
Ditto, Hemideutoxide of (Peroxide).....	..	Oxygen..... Cerium.....	14 1	12 50	62	(Do.)	Ditto, Tetartoxide of (Nitric Acid).....	G.	Oxygen..... Nitrogen.....	4 1	32 14	46	(457)
Chlorine, Protoxide of (Vachlorine).....	..	Oxygen..... Chlorine.....	1 1	8 36	44	(144)	Ditto, Pemptoxide of (Nitric Acid).....	G.	Oxygen..... Nitrogen.....	5 1	40 14	54	(458)
Ditto, Tritoxide of.....	..	Oxygen..... Chlorine.....	3 1	24 36	60	(145)	Osmium.....	S.	Oxygen..... Osmium.....	1 1	8 56	64	(920)
Ditto, Tetartoxide of (Peroxide D).....	..	Oxygen..... Chlorine.....	4 1	32 36	64	(146)	Palladium, Protoxide of.....	S.	Oxygen..... Palladium.....	1 1	8 96	104	(942)
Ditto, Pemptoxide of (Chloric Acid).....	..	Oxygen..... Chlorine.....	5 1	40 36	76	(147)	Platinum, Protoxide of.....	S.	Oxygen..... Platinum.....	1 1	8 96	104	(942)
Ditto, Heptoxide of (Perchloric Acid).....	..	Oxygen..... Chlorine.....	7 1	56 36	92	(148)	Ditto, Deutoxide of (Peroxide of P.).....	S.	Oxygen..... Platinum.....	2 1	16 96	112	(942)
Chromium, Protoxide of.....	..	Oxygen..... Chromium.....	1 1	8 28	36	(725)	Potassium, Protoxide of (Potassa).....	S.	Oxygen..... Potassa.....	1 1	8 40	48	(625)
Ditto, Deutoxide of.....	..	Oxygen..... Chromium.....	2 1	16 28	44	(Do.)	Ditto, Tritoxide of (Peroxide of P.).....	S.	Oxygen..... Potassa.....	3 1	24 40	64	(617)
Ditto, Tritoxide of (Chromic Acid).....	..	Oxygen..... Chromium.....	3 1	24 28	52	(723)	Rhodium, Protoxide of.....	S.	Oxygen..... Rhodium.....	1 1	8 44	52	(934)
Cobalt, Protoxide of.....	..	Oxygen..... Cobalt.....	1 1	8 26	34	(790)	Ditto, Deutoxide of (Peroxide of R.).....	S.	Oxygen..... Rhodium.....	2 1	16 44	60	(Do.)
Ditto, Hemideutoxide of.....	..	Oxygen..... Cobalt.....	14 1	12 26	38	(Do.)							
Columbium, Protoxide of (Columbic Acid).....	..	Oxygen..... Columbium.....	1 1	8 14	152	(734)							
Copper, Suboxide of (Red Oxide).....	..	Oxygen..... Copper.....	1 2	8 64	72	(895)							

Substance.	State.	Elements.	No. of Atoms.	Constituent Proportions of Weight.	Total Weight of Atoms referred to Hyd.	Article in this Treatise.	Substance.	State.	Elements.	No. of Atoms.	Constituent Proportions of Weight.	Total Weight of Atoms referred to Hyd.	Article in this Treatise.
Silver, Protoxide of.....	S.	Oxygen .....	1	8	118	(908)	Iron, Hemideuto-tri-phosph. of (Peri-tri-phosph.).....	..	Phosphoric Acid.	1	98	175	
Sodium, Protox. of (Soda)	S.	Silver .....	1	110	82	(605)	Lead, Proto-phosph. of....	A.	Hemideutox. Iron Water .....	3	180	140	
Ditto, Hemideutoxide of (Peroxide of) .....	S.	Oxygen .....	1	8	36	(600)	Lead, Proto-diphosphate of	A.	Phosphoric Acid.	1	98	258	
Strontium, Protoxide of (Strontia) .....	S.	Sodium .....	1	24	52	(583)	Lime, Phosphate of.....	A.	Protox. Lead .....	1	112	56	
Sulphur, Protoxide of (Hypo-sulphurous Acid) ..	..	Oxygen .....	1	8	24	(388)	Ditto Semi-diphosphate of (Apatite) .....	A.	Phosphoric Acid.	1	98	70	
Ditto, Deutoxide of (Sulphurous Acid) .....	G.	Sulphur .....	1	16	32	(389)	Magnesia, Phosphate of ..	..	Lime .....	1	42	111	
Ditto, Hemitritoxide off (Hypo-sulphuric Acid) ..	..	Oxygen .....	2	16	36	(390)	Mercury, Proto-phosphate of .....	A.	Phosphoric Acid.	1	98	236	
Ditto, Tritoxide of (Sulphuric Acid) .....	A.	Sulphur .....	1	16	40	(391)	Nickel, Proto-phosphate of	..	Protox. Merc. ....	1	108	89	
Ditto, Ditto .....	L.	Oxygen .....	3	24	40	(391)	Potassa, Phosphate of....	..	Phosphoric Acid.	1	98	85	
Tellurium, Protoxide of (Telluric Acid) .....	..	Sulphur .....	1	16	40	(391)	Soda, Phosphate of .....	..	Potassa .....	1	98	168	
Tin, Protoxide of .....	..	Dry Acid .....	1	40	40	(Do.)	Ditto, Biphosphate of....	..	Water .....	1	9	119.5	
Ditto, Deutoxide of (Peroxide) .....	..	Water .....	1	9	40	(Do.)	Strontia, Phosphate of....	..	Phosphoric Acid.	1	98	89	
Titanium, Protoxide of...	..	Oxygen .....	1	8	40	(837)	Ditto, Biphosphate of....	..	Soda .....	1	31.5	126	
Ditto, Deutoxide of (Titanic Acid) .....	..	Tellurium .....	1	32	66	(663)	Zinc, Phosphate of .....	..	Water .....	1	9	88	
Tungsten, Deutoxide of (Browa oxide) .....	..	Oxygen .....	2	16	74	(Do.)	Phosphites.	S.	Phosphorus.....	..	..	12	(344)
Uranium, Protoxide of...	..	Tin .....	1	58	40	(801)	Phosphurets.	..	Phosphuretted Hydrogen (see Hydrogen of Pa.)	..	..	..	
Ditto, Deutoxide of (Titanic Acid) .....	..	Oxygen .....	2	16	48	(809)	Picromel .....	..	Picrotolime .....	..	..	..	(1070)
Tungsten, Deutoxide of (Tungstic Acid) .....	..	Tungsten .....	1	96	112	(737)	Platinum .....	S.	Polychroite .....	..	..	..	(1011)
Ditto, Tritoxide of (Tungstic Acid) .....	..	Oxygen .....	3	24	120	(744)	Potassa (see Oxide of Potassium) .....	S.	Potassium .....	..	..	48	(825)
Uranium, Protoxide of...	..	Uranium .....	1	208	216	(770)	Promethium (see Hydrocyanates)	S.	Promethium .....	..	..	40	(614)
Ditto, Deutox. of (Peroxide)	..	Oxygen .....	2	16	224	(776)	Prussic Acid (see Hydrocyanic Acid) .....	..	Quinn-silver (see Mercury)	L.	..	..	(474)
Yttrium, Protoxide of (Ytria) .....	..	Yttrium .....	1	34	42	(493)	Quinn-silver (see Mercury)	S.	Quinn-silver .....	S.	..	..	(870)
Zinc, Protoxide of .....	..	Oxygen .....	1	8	42	(678)	Resins .....	R.	Rhodium .....	R.	..	..	(1008)
Zirconium, Protoxide of (Zirconia) .....	..	Zinc .....	1	34	48	(480)	Rhodium .....	S.	Saliva .....	L.	..	..	(987)
Oxidates (see Iodates) ..	..	Oxygen .....	..	..	..	(226)	Saccharates.	..	Saccharine .....	S.	..	..	(1017)
Oxygen .....	..	Oxygen .....	..	..	..	(121)	Saliva .....	L.	Selenites .....	S.	..	..	(928)
Oxyanurates (see Chlorates)	..	Oxygen .....	..	..	..	(147)	Selenites .....	S.	Seleniuretted Hydrogen (see Hydro-selenic Acid).	..	..	..	(487)
Palladium .....	S.	Oxygen .....	..	..	..	(817)	Silica .....	..	Oxygen .....	1	8	40	(409)
Pancreatic Juice .....	L.	Oxygen .....	..	..	..	(1069)	Silicon .....	S.	Silicon .....	1	28	40	(490)
Pectic Acid .....	..	Oxygen .....	..	..	..	(902)	Silver .....	S.	Soda (see Oxide of Sodium)	..	..	..	(961)
Piperine .....	S.	Oxygen .....	..	..	..	(1054)	Soda .....	S.	Bolonia .....	..	..	..	(968)
Phosgene Gas (see Chloro-carbonic Acid Gas) .....	G.	Zinc .....	1	34	48	(480)	Spirit of Wine (see Alcohol)	L.	Spirit of Wine .....	..	..	..	(1012)
Phosphates.	..	Zirconium .....	1	40	8	(226)	Starch .....	S.	Starch .....	..	..	..	(1022)
Alumina, Phosphate of...	..	Oxygen .....	..	..	..	(226)	Strontia (see Oxide of Strontium) .....	S.	Strontia .....	..	..	..	(563)
Ammonia, Phosphate of...	..	Alumina .....	1	18	70	(147)	Styria .....	S.	Styria .....	..	..	..	(1007)
Ditto, Biphosphate of .....	A.	Water .....	3	27	63	(817)	Sulphates.	..	Sulphuric Acid ..	1	40	191	
Baryta, Phosphate of .....	A.	Phosphoric Acid.	1	98	106	(817)	Alumina, Sulphate of....	..	Alumina .....	1	18	68	
Bismuth, Proto-phosph. of	..	Ammonia .....	1	16	136	(1069)	Ditto, Disulphate of .....	..	Water .....	1	18	68	
Cadmium, Proto-phosph. of	..	Water .....	2	16	101	(1069)	Sulphuric Acid ..	..	Alumina .....	1	18	68	
Cobalt, Proto-phosph. of...	..	Phosphoric Acid.	1	98	80	(1069)	Sulphuric Acid ..	..	Alumina .....	1	18	68	
Copper, Proto-phosph. of...	..	Protox. Cadm. ....	1	9	77	(1069)	Sulphuric Acid ..	..	Alumina .....	1	18	68	
Ditto, Ditto, Ant. ....	A.	Water .....	1	9	68	(1069)	Sulphuric Acid ..	..	Alumina .....	1	18	68	
Iron, Proto-phosph. of ..	..	Phosphoric Acid.	1	98	91	(1069)	Sulphuric Acid ..	..	Alumina .....	1	18	68	
	..	Protox. Iron .....	1	26	27	(1069)	Sulphuric Acid ..	..	Alumina .....	1	18	68	
	..	Water .....	3	27		(1069)	Sulphuric Acid ..	..	Alumina .....	1	18	68	

TABLE XII. *continued.*

Substance.	State.	Elements.	No. of Atoms.	Constituent Proportions by Weight.	Total Weight of Atoms referred to Hyd.	Article in this Treatise.	Substance.	State.	Elements.	No. of Atoms.	Constituent Proportions by Weight.	Total Weight of Atoms referred to Hyd.	Article in this Treatise.
Alumina, Trisulphate of...	..	Sulphuric Acid .. Alumina..... Water.....	1 3 9	40 54 81	175		Baryum, Sulphuret of....	..	Sulphur..... Baryum..... Sulphur.....	1 1 1	16 70 16	66	
Ammonia, Sulphate of....	..	Sulphuric Acid .. Ammonia..... Water.....	1 1 1	40 17 9	66		Bismuth, Sulphuret of ...	..	Bismuth..... Sulphur..... Sulphur.....	1 1 1	16 71 16	68	
Baryta, Sulphate of .....	A.&C.	Sulphuric Acid..... Baryta..... Sulphuric Acid ..	1 1 1	40 78 40	118		Cadmium, Sulphuret of...	..	Sulphur..... Cadmium..... Sulphur.....	1 1 1	16 56 16	72	
Bismuth, Proto-sulph. of..	..	Sulphuric Acid .. Protox. Bism..... Sulphuric Acid ..	1 1 1	40 80 40	120		Calcium, Sulphuret of....	..	Sulphur..... Calcium..... Sulphur.....	1 1 1	16 30 16	26	
Cadmium, Proto-sulph. of..	C.	Sulphuric Acid .. Protox. Cadm..... Water.....	1 1 1	40 64 86	140		Cadmium, Sulphuret of....	..	Sulphur..... Cadmium..... Sulphur.....	1 1 1	16 56 16	68	
Calcium, Proto-sulph. of ..	..	Sulphuric Acid .. Protox. Calcium..... Water.....	1 1 3	40 58 27	125		Chromium, Sulphuret of..	..	Sulphur..... Chromium..... Sulphur.....	1 1 1	16 28 16	44	
Cobalt, Proto-sulph. of....	..	Sulphuric Acid .. Protox. Cobalt..... Water.....	1 1 7	40 34 63	137		Cobalt, Sulphuret of.....	..	Sulphur..... Cobalt..... Sulphur.....	1 1 1	16 36 16	48	
Ditto, Proto-bisulph. of...	..	Sulphuric Acid .. Protox. Cobalt..... Water.....	2 1 3	80 34 27	141		Columbium, Sulphuret of..	..	Sulphur..... Columbium..... Sulphur.....	1 1 1	16 144 16	160	
Copper, Proto-sulph. of...	..	Sulphuric Acid .. Protox. Copper..... Water.....	1 1 5	40 45 45	125		Copper, Disulphuret of...	..	Sulphur..... Copper..... Sulphur.....	2 1 1	32 64 16	80	
Glycyrrhiza, Bisulph. of .....	..	Sulphuric Acid .. Glycyrrhiza..... Water.....	2 1 5	80 36 45	151		Ditto, Sulphuret of.....	..	Copper..... Sulphur..... Copper.....	2 1 2	32 16 32	64	
Iron, Proto-sulph. of.....	..	Sulphuric Acid .. Protox. Iron..... Water.....	1 1 7	40 36 63	139		Gold, Tersulphuret of...	..	Sulphur..... Gold..... Sulphur.....	3 1 1	48 200 16	248	
Ditto, Hemiduto-semi-bisulph. of (Perseusulph.)	..	Sulphuric Acid .. Hemidutox. Iron..... Water.....	1 1 1	40 40 1	?		Iron, Sulphuret of.....	..	Sulphur..... Iron..... Sulphur.....	1 1 1	16 24 16	44	
Lead, Proto-sulph. of....	..	Sulphuric Acid .. Protox. Lead..... Sulphuric Acid ..	1 1 1	40 112 40	152		Ditto, Bisulphuret of....	..	Sulphur..... Lead..... Sulphur.....	2 1 2	32 104 32	136	
Lime, Sulph. of (Selenite).	..	Sulphuric Acid .. Lime..... Water.....	1 1 2	40 28 18	86		Lithium, Sulphuret of....	..	Sulphur..... Lithium..... Sulphur.....	1 1 1	16 104 16	120	
Ditto Ditto.....	A.	Sulphuric Acid .. Lime..... Sulphuric Acid ..	1 1 1	40 28 40	68		Magnesium, Sulphuret of..	..	Sulphur..... Magnesium..... Sulphur.....	1 1 1	16 124 16	140	
Lithia, Sulph. of .....	..	Sulphuric Acid .. Lithia..... Water.....	1 1 1	40 18 9	67		Manganese, Sulphuret of..	..	Sulphur..... Manganese..... Sulphur.....	1 1 1	16 28 16	44	
Magnesia, Sulph. of (Epsom Salt) .....	..	Sulphuric Acid..... Magnesia..... Water.....	1 1 7	40 20 63	123		Mercury Sulphuret of...	..	Sulphur..... Mercury..... Sulphur.....	2 1 2	32 200 32	232	
Manganese, Proto-sulph. of	C.	Sulphuric Acid .. Protox. Mangan..... Water.....	1 1 5	40 36 45	121		Ditto, Bisulphuret of....	..	Sulphur..... Mercury..... Sulphur.....	2 1 2	32 200 32	232	
Mercury, Proto-sulph. of..	..	Sulphuric Acid .. Protox. Merc..... Water.....	1 1 2	40 208 18	266		Nickel, Sulphuret of....	..	Sulphur..... Nickel..... Sulphur.....	1 1 1	16 96 16	104	
Ditto, Deuto-sulph. of....	A.	Sulphuric Acid .. Deutox. Merc..... Sulphuric Acid ..	1 1 1	40 216 40	256		Palladium, Sulphuret of..	..	Sulphur..... Palladium..... Sulphur.....	1 1 1	16 56 16	72	
Nickel, Proto-sulph. of ..	..	Sulphuric Acid .. Protox. Nickel..... Water.....	1 1 7	40 34 63	137		Platinum, Sulphuret of...	..	Sulphur..... Platinum..... Sulphur.....	1 1 2	16 96 32	112	
Platinum, Deuto-sulph. of.	A.	Sulphuric Acid .. Deutox. Plat..... Sulphuric Acid ..	1 1 1	40 112 40	152		Ditto, Bisulphuret of....	..	Sulphur..... Platinum..... Sulphur.....	2 1 2	32 96 32	128	
Potassa, Sulphate of.....	C.&A.	Sulphuric Acid .. Potassa..... Sulphuric Acid ..	1 1 1	40 48 40	89		Potassium, Sulphuret of..	..	Sulphur..... Potassium..... Sulphur.....	1 1 1	16 40 16	56	
Ditto, Bisulphate of.....	C.&H.	Sulphuric Acid .. Potassa..... Water.....	2 1 2	80 44 14	146		Ditto, Bisulphuret of....	..	Sulphur..... Potassium..... Sulphur.....	2 1 2	32 40 32	72	
Silver, Proto-sulphate of ..	C.&A.	Sulphuric Acid .. Protox. Silver..... Sulphuric Acid ..	1 1 1	40 118 40	158		Ditto, Tersulphuret of...	..	Sulphur..... Potassium..... Sulphur.....	3 1 1	48 40 16	88	
Soda, Sulphate of (Glauber's Salt) .....	C.&H.	Sulphuric Acid .. Soda..... Water.....	1 1 10	40 28 90	168		Ditto, Quatersulphuret of.	..	Sulphur..... Potassium..... Sulphur.....	4 1 1	64 40 16	104	
Strontia, Sulphate of .....	C.&A.	Sulphuric Acid .. Strontia..... Sulphuric Acid ..	1 1 1	40 52 40	92		Ditto, Quatersulphuret of.	..	Sulphur..... Potassium..... Sulphur.....	5 1 1	80 40 16	120	
Uranium, Deuto-semi-bisulphate of .....	C.&H.	Sulphuric Acid .. Deutox. Uran..... Water.....	1 1 4	40 224 36	320		Rhodium, Sulphuret of...	..	Sulphur..... Rhodium..... Sulphur.....	1 1 1	16 44 16	60	
Yttria, Sulphate of .....	C.&H.	Sulphuric Acid .. Yttria..... Water.....	1 1 1	40 48 14	146		Silver, Sulphuret of.....	..	Sulphur..... Silver..... Sulphur.....	1 1 1	16 110 16	126	
Zinc, Proto-sulphate of...	C.&H.	Sulphuric Acid .. Protox. Zinc..... Water.....	1 1 7	40 42 63	145		Sodium, Sulphuret of....	..	Sulphur..... Sodium..... Sulphur.....	1 1 1	16 24 16	40	
Sulphates.	B.	.....	..	..	16	(376)	Strontium, Sulphuret of ..	..	Sulphur..... Strontium..... Sulphur.....	1 1 1	16 44 16	60	
Sulphurets.	..	.....	..	..	..	..	Tin, Sulphuret of .....	..	Sulphur..... Tin..... Sulphur.....	1 1 1	16 58 16	74	
Arsenic, Sulphuret of ....	..	Sulphur..... Arsenic..... Sulphur.....	1 1 1	16 23 16	54		Ditto, Semi-bisulphuret of (Sequoisulphuret) .....	..	Sulphur..... Tin..... Sulphur.....	1 1 2	16 58 32	82	
Ditto, Semi-bisulphuret of	..	Sulphur..... Arsenic..... Sulphur.....	1 1 1	16 23 16	69		Ditto, Bisulphuret of ....	..	Sulphur..... Tin..... Sulphur.....	2 1 2	32 58 32	90	
Antimony, Sulphuret of ..	..	Sulphur..... Antimony..... Sulphur.....	1 1 1	16 44 16	60		Titanium, Sulphuret of ..	..	Sulphur..... Titanium..... Sulphur.....	1 1 1	16 32 16	48	
	..	.....	..	..	..	..	Uranium, Sulphuret of ...	..	Sulphur..... Uranium..... Sulphur.....	1 1 1	16 208 16	224	
	..	.....	..	..	..	..	Zinc, Sulphuret of .....	..	Sulphur..... Zinc..... Sulphur.....	1 1 1	16 65 16	50	
	..	.....	..	..	..	..	Sulphuretted hydrogen (Hydro-sulphuric Acid)	..	.....	..	..	..	(1706)
	..	.....	..	..	..	..	Synovia	..	.....	..	..	..	(1040)
	..	.....	..	..	..	..	Taxin	..	.....	..	..	..	(996)
	..	.....	..	..	..	..	Tellurets	..	.....	..	..	..	(840)
	..	.....	..	..	..	..	Telluretted Hydrogen (Hydro-telluric Acid)	..	.....	..	..	..	

TABLE XII. *continued.*

Substance.	State.	Elements.	No. of Atoms.	Constituent Proportions by Weight.	Total Weight of Atoms referred to Hyd.	Article in this Treatise.	Substance.	State.	Elements.	No. of Atoms.	Constituent Proportions by Weight.	Total Weight of Atoms referred to Hyd.	Article in this Treatise.
Tellurium .....	S.	.....	..	..	32	(834)	Urea .....	C.	.....	..	..	..	(1089)
Thorium .....	S.	.....	..	..	..	(518)	Urine .....	L.	.....	..	..	..	(1095)
Thorium .....	S.	.....	..	..	..	(100)	Veratrin .....	C.	.....	..	..	..	(1009)
Tin .....	S.	.....	..	..	58	(680)	Vinous fermentation .....	C.	.....	..	..	..	(1069)
Titanium .....	S.	.....	..	..	32	(798)	Volatile Alkali (Ammonia) .....	G.	.....	..	..	..	(489)
Tungstater .....	S.	.....	..	..	126	(734)	Water .....	L.	Hydrogen .....	1	1	9	(393)
Tungsten .....	S.	.....	..	..	126	(734)	Yeast .....	L.	Oxygen .....	1	8	9	(1039)
Turpentine .....	L.	.....	..	..	..	(1018)	Yitria .....	S.	.....	..	..	..	(495)
Ulmia .....	S.	.....	..	..	..	(1089)	Yitrim .....	S.	.....	..	..	34	(495)
Uranium .....	S.	.....	..	..	208	(767)	Zinc .....	S.	.....	..	..	42	(679)
Urates .....	..	.....	..	..	..	(1073)	Zirconia .....	S.	.....	..	..	48	(489)
							Zirconium .....	S.	.....	..	..	40	(489)

*Note.* From the use of descriptive names in this Table, it must not be inferred that these are designed in all cases to supersede those already in use: thus, for instance, among the Oxides, Peroxide of Nitrogen is placed in the first column to preserve the harmony of the system of nomenclature, and to inculcate a descriptive appellation, but the synonyme, Nitric Acid, is well established, and will doubtless continue in use.

In Art. (878.) an inaccuracy exists, the origin of which we cannot comprehend. The union of Selenium with Mercury should have been noticed under Art. (877.); whilst under (878.) I. it should have been stated that Mercury has generally a strong tendency to unite with other Metals; and that it refuses to do so in very few, and even these uncertain, cases.

In Art. (111.) the reader is requested to erase a paragraph of four lines, beginning "The definite," &c at the ninth line from the end, as it has been found necessary to abandon that plan, and to confine the prefixes *Prot*-, *Deut*-, &c. to the oxides only.

# MINERALOGY.

mineralogy

## Introductory Observations.

(1.) MINERALOGY is defined by Kirwan to be *the Art of distinguishing Mineral substances from each other.*

All bodies found in or upon the earth, not being vegetable or animal, are termed Minerals.

(2) It has been stated in the Introduction to Crystallography, that we are indebted to Haüy for the first satisfactory explanation of the mutual relations of crystalline forms; and it is also due to his memory to add, that his views of Mineralogy were more precise and philosophical than those of any author by whom life had been preceded. In recommending this pursuit to the favourable notice of others, he observes, that if the motives by which we are led to the cultivation of any branch of Natural Science, were founded solely upon the pleasure afforded by a casual inspection of the productions to which it relates, Zoology and Botany would claim our first regard; but that if we overcome this first unfavourable impression, and look a little more closely to only a few individuals belonging to the Mineral kingdom, we shall, he says, find them possessed of a regularity of structure, an almost infinite variety of distinct, yet related forms, and many other properties, not only capable of affording a high degree of interest, but offering inducements to the collector of Minerals to enter upon a wider range of philosophical inquiry.

The necessity of exact Mineralogical knowledge to the Geologist has been very justly and forcibly expressed by Mr. Aikin in the introduction to his *Manual of Mineralogy*, published in 1815. He says: "The absolute necessity of extreme accuracy in discriminating one species of Mineral from another is too obvious to require any further remark, if examples were not perpetually presenting themselves of persons very slenderly provided with these rudiments of the Science, who yet undertake geological investigations, and with a peremptoriness, generally in proportion to their ignorance, challenge the credit of new discoveries, or fall in question the observations of their predecessors." "It is, indeed, very true that geological speculations are as fascinating to the student as the discrimination of species is generally repulsive; yet it ought to be borne in mind that as all sound scholarship is founded upon Grammar, so all sound Geology depends primarily on a familiar acquaintance with the distinctive characters of simple Minerals."

## Of Mineral Species.

(3.) If we examine specimens of the various kinds of Minerals, they will be found to differ considerably in form and colour: some will be opaque, others more or less transparent; and among those which are transparent, some may be observed to produce a double image of the objects seen through them. If the specimens are taken in the hand, some will be found much heavier than others of the same apparent size. If an attempt be made to scratch them with a pin or needle, some will be readily marked by the pin, others will require the steel

point to produce the same effect; and others will not be scratched by either. Some may be cut with a knife into thin slices, while an attempt to cut others will produce only powder or fragments, and many will entirely resist the action of the knife. Some may be hammered into thin plates, while others will only be bruised to powder, or broken into angular fragments with plain or curved surfaces.

(4.) If the different specimens were to be analyzed by the Chemist, many of them would agree, and many differ in their composition, apparently denoting identity or difference of kind among the Minerals examined; and it might be expected that such Minerals would also be distinguished by corresponding resemblances or disagreements in their external and other characters. But it would occasionally be perceived that specimens which agreed in their chemical composition, exhibited differences in some of their external characters; and that others which agreed in their external characters, differed in their chemical composition. There would, however, generally be found among the external or physical characters some which so constantly accompany particular chemical kinds, as to warrant the conclusion that such characters are essential to such kinds; but it must be admitted that, until the relations between the chemical and other properties shall be more correctly ascertained, the separation of all the known Minerals into kinds or species, must, in many instances, be regarded as provisional only, and subject to alterations as their properties become better understood.

(5.) It appears from chemical analysis that carbonate of lime which occurs generally in *rhomboids*, as in the common calcareous spar, occurs also in *rhombic prisms*, as in arragonite; and hence it follows that the same elements are subject to different modes of crystalline arrangement. It is apparent that carbonate of lime and arragonite might, from the similarity of their composition, be regarded as belonging to the same natural species; while the differences in their form and in their physical properties, which are also natural characters, would require them to be considered as distinct natural species; but as the practical purpose for which Minerals are divided into species, that of affording the means of distinguishing them from each other, is more completely answered by regarding them as different species, they have been so considered by previous writers on Mineralogy. This property of crystallizing under two distinct forms has been termed *dimorphism*; and in order to preserve a consistent Mineralogical rule, all dimorphous substances ought to form two species; and even sulphur, although a simple chemical body, as it crystallizes under two separate forms, ought not, perhaps, to become an exception to the rule. Hence it is obvious that there might be two distinct natural systems of classification of Minerals, distinguished as the *Chemical* and *Mineralogical*; and if all the discrepancies between Chemical and Mineralogical species were analogous to those of carbonate of lime and arragonite, there would be little difficulty in classing and arranging the whole according to either of these methods. But there are other anomalies

*Mineralogy* in the relations of the composition and form of Minerals, arising out of what has been termed the *isomorphism* of their molecules, which tend still further to embarrass the distinction of species among several well-known substances. On this subject, however, we must refer our readers to some papers in the Xth volume of the *Phil. Mag. and Annals of Philosophy*, and to the *Reports of the British Association for the Advancement of Science*.

(6.) In addition to the uncertainties already noticed in the determination of Mineral species, some further difficulty may occasionally be experienced from the changes which are found to have taken place in the substance of Minerals, without any alteration of external form or cleavage. A Mineral so altered has been termed *epigene* by Haüy; and examples of such changes may be observed in iron pyrites, where the sulphur has left the iron, and oxygen has taken its place; and in carbonate of iron, where the carbonic acid has quitted the Mineral, and left it in the state of an oxide. In both these instances the crystalline forms of the pyrites and carbonate of iron are retained.

(7.) The substance of one Mineral is also occasionally found to have been destroyed or removed, and to have been replaced by that of another, which yet retains the form of the original substance, a change to which the term *pseudomorphism* has been applied. It is not unfrequent among Minerals, but its causes are involved in great obscurity.

(8.) It has also been supposed that Minerals may pass from one species into another. As where two distinct species are so mixed, that neither should appear to predominate or envelope the particles of the other, and to assume its proper form and other characters. But the only difficulty that could present itself in this case would arise, not from the compound exhibiting a *false* character, but from its being destitute of *any* precise specific character.

#### Of Classification.

(9.) Let us suppose that the physical and chemical characters of all the varieties of known Minerals have been ascertained and accurately recorded. The next proceeding of the owner of such a collection would probably be an attempt to arrange these descriptions, so as to exhibit the *natural* relations of the different kinds to each other. In attempting to effect which object, he would immediately perceive that there might be as many different systems of *natural* classification as there are distinct natural characters among Minerals. And hence his first difficulty would be the selection of the particular characters which might afford the best foundation of his *natural* arrangement; but for reasons which we have not space here to discuss, he would probably adopt the chemical composition as his basis.

(10.) Let us now imagine the supposed collection to have been destroyed, and the possessor of it to be desirous of again forming a similar one, with no other assistance than the descriptions that have been preserved of the lost specimens.

As these recorded descriptions are supposed to have been either noted down promiscuously, or to have been afterwards arranged according to composition, it is obvious that however correctly they may have been recorded, they would afford little assistance in identifying new specimens; for the time and labour that would be required for successively comparing each new specimen

with each individual description of those which had been destroyed, would render the attempt impracticable.

In order, therefore, to facilitate the recognition of species from recorded descriptions, and thus to practise the *Art of Mineralogy*, it would be found necessary to classify and arrange the several characters with a view to this particular object, and thus to produce what may be termed an *artificial* arrangement.

Mineralogy may therefore be regarded both as a Science and an Art. As a Science in reference to the knowledge requisite for supplying accurate descriptions of Minerals, and forming what may be termed a *natural* classification; and an Art in reference to the arrangement of the descriptive characters for the purpose of afterwards distinguishing Minerals from each other.

(11.) Before we proceed to explain the methods which have been adapted to these purposes, we shall follow Berzelius in a hasty review of the History of Mineralogy, and the methods of classification adopted by preceding authors.

Little is to be discovered in the writings of the Ancients relative to Mineralogy in the modern sense of that term. On the contrary, the earliest histories and descriptions of Minerals are interspersed with fabulous accounts, such as Pliny has recorded of the diamond; which he says is so hard that no blow of the hammer will break it, but that when struck upon an anvil, it will rather split both the anvil and the hammer than suffer itself to be broken, unless it be previously steeped in the blood of a goat recently killed.

The first attempts at a methodical arrangement of Minerals, and the first use of the term *Mineral Kingdom* must be referred to the XVIIth Century, within which period many different systems, or Mineralogical methods, have been published. Some founded on external and physical characters only; others uniting the chemical character to these; and some later ones being strictly chemical.

Wallerius, one of the most distinguished of the early writers, arranged his *species* of Minerals by some of their external and physical characters; such as texture, fracture, figure of the fragments, colour, transparency, hardness, as evinced by giving sparks with steel, effervescence with acids, &c. The systems of Brunner and of Cronstedt were also founded on external characters, and consisted of four principal subdivisions:

Earths,	Bitumens,
Salts,	Metals.

And each of these classes was subdivided into the following orders, dependent on texture or structure.

1. Earthy,	5. Fibrous,
2. Scaly,	6. Granular-foliated,
3. Foliated,	7. Compact.
4. Radiated,	

The salts being further determined by their flavour; as  
Astringent, Sweet,  
Acid, Salt, &c.

These systems, it may be observed, were founded at a period when Chemistry had made comparatively little progress; but as that Science improved, we find it resorted to by Mineralogists for supplying other distinguishing characters.

The systems of Werner and of Haussmann were founded upon the chemical and external characters conjointly; and that of Werner was for a considerable period almost exclusively adopted by Mineralogists. It was not, however, published by the author himself, and

Mineralogy coming only through the hands of his pupils, may possibly not have always represented his views with accuracy.

The following is an outline of his method of classification:

- Class 1. Earthy Minerals.
- Class 2. Saline Minerals.
- Class 3. Inflammables.
- Class 4. Metals.

In this system the advantages which might result to the Science from any single *natural* method, are unavailable to the student. For the chemical arrangement is continually violated to preserve an apparent consistency in that founded on external characters, which, in its turn, is not unfrequently disturbed by the regard paid to chemical constitution. And hence its followers have seldom agreed concerning the proper place which new Minerals ought to occupy in that system. The system of Haussmann was also founded upon a chemical basis, but more perfect than that of Werner, and was also combined with the consideration of external characters. And hence the disadvantage of attempting to combine conflicting and incompatible systems, was as apparent in this as it had been in the system of Werner.

The principal systems founded on a more strictly chemical basis were first those of Karsten and of Haüy, and, at a later period, of Brongniart, Cleveland, and Phillips; that of Karsten may be said to present the dawn of an attempt at accurate *natural* classification, which has been greatly improved in the hands of Haüy, and has derived still greater advantages from the labours of Berzelius. We shall, therefore, enter no further into the system of Karsten than to say, that its leading divisions are into

1. Earths, 2. Salts,  
containing all the soluble varieties arranged according to their acids,

3. Combustibles, 4. Metals.

(12.) The system of Haüy was first published in 1801, and a second edition in 1822.

His definition of a Mineral species is, that all the individuals belonging to it *shall be similar in their composition*, and that their *crystalline forms shall also be similar*. It is obvious from what has preceded that this definition cannot be universally applied. If, he says, we collect crystals of quartz from different parts of the World, we shall observe such a general resemblance among them as would lead to a conclusion of their being similar Minerals. If we examine them chemically, we are supported in this conclusion; and if we measure their angles, we shall find such an agreement among the corresponding ones of different crystals as to leave no doubt that they all belong to one species. Let us now, he says, take a rolled pebble whose lustre, when broken, resembles the fractured parts of crystals of quartz. We analyze the substance, and find it nearly pure siliceous; we place it in a position in which we may observe the light reflected from its fractured surface, and we perceive that from some parts of that surface not only the rays of light, but the images of objects, are distinctly reflected; we consider those parts as portions of cleavage planes, we detach and measure some fragments, and we discover angles corresponding with some of those presented by the regular crystals of quartz; we therefore include our specimen under the species quartz. We proceed with another specimen of what is termed white cornelian, whose structure is fibrous, whose frag-

ments afford but dull reflections of light, and not any images of surrounding objects. This differs so much in character from the preceding specimens, that at first view we should exclude it from the species. But on analysis, we find that its composition is very nearly similar to that of rock crystals; and as an analogy has been observed to subsist between the crystallized and fibrous structure of other Minerals, we place our white cornelian as a variety of the species quartz.

The following is an outline of the classification adopted by Haüy:

Class 1. Free acids.

Class 2. Metals appearing under another character. (Heteropsides.) These are the earthy Minerals.

Appendix to class 2. The characteristic principle depending upon the siliceous not yet determined, and being free or combined.

Class 3. Metals appearing as such. (Autopsides.)

Order 1. Not immediately oxidable, unless at a very high temperature, and immediately reducible.

Order 2. Oxidable, and reducible immediately.

Order 3. Oxidable, but not immediately reducible.

a. Sensibly ductile.

b. Not ductile.

Class 4. Combustibles, not metallic.

An appendix to this class, consisting of substances of vegetable origin.

Appendix to the four preceding Classes.

22 substances.

This classification appears equally objectionable with those preceding it, exhibiting as it does a mixture of chemical and physical characters in the same system.

We pass over the systems of Brongniart, Cleveland, Phillips, Breithaupt, Beudant, and other authors who have intervened between the first publication of Haüy's method and the present time, not as unworthy of more particular notice, but because they may be regarded as varieties of the chemical method, modified in a greater or less degree by the introduction of some other principle.

We are indebted to Berzelius for the first attempt at a strictly chemical classification of Minerals. According to this author's system, all chemical compounds are supposed to consist of electro-positive and electro-negative particles, attracted and held together by a force analogous to that by which bodies in different states of electricity are influenced. When Minerals are analyzed, therefore, and their simple constituent parts ascertained, we are, according to this theory, to regard those of the electro-positive and electro-negative elements which present themselves in *such definite proportions as are consistent with the atomic theory, to be essential elementary parts of the Mineral examined*; and upon this principle a general determination of Mineral species has been attempted, and a systematic classification founded.

But this author has candidly acknowledged the difficulties which, in the present state of Chemical Science, attend the inquiry into what are really the essential constituents of Minerals. The first is that of ascertaining correctly, by means of analysis, the nature of all the different kinds of particles which enter into the composition of a compound Mineral, and the still greater difficulty of determining the exact proportions of each kind. This, however, may possibly be overcome by further improvements in practical Chemistry. But the second, and as



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it appears to us the insurmountable impediment to the establishment of an accurate chemical determination of Mineral species, arises from the extraneous matter which is so frequently, we might almost say universally, found accompanying the essential constituents of the Mineral.

The substance known by the name of Fountainebleau sandstone affords a striking instance of this kind of composition. This Mineral may be regarded either as granular quartz cemented by carbonate of lime, or as carbonate of lime enveloping grains of quartz, yet no one has ever regarded this mixture as constituting a new chemical species. Instances also occur in which only part of a specimen is coloured by foreign matter, which, if it had pervaded the whole specimen, the Chemist would be deceived by analysis, and would erect an accidental variety of some known Mineral into a new species.

On looking over the number of species which Berzelius has formed out of the garnet tribes, it is much to be suspected that accidental mixtures have been reckoned among the essential constituents of several of the varieties examined; a suspicion which may be reasonably entertained from the manner in which the chemical formulæ of Minerals is made up. For we can scarcely imagine a compound, however heterogeneous, whose constituent particles may not be so parcelled out as to appear nearly definitely proportional to each other. It is, however, very possible that some of the Minerals hitherto called garnets, on account of their crystalline form, may really be different substances. But the number of Mineral species which may fairly be regarded as doubtful on account of some supposed heterogeneous mixture of elements will probably be continually reduced by new and more correct analyses; with a due regard to the matrix, to the accompanying substances, and to the purity of the specimens analyzed, as far as that can be judged of from their transparency and other characters.

The order established by the *electro-chemical* relation of bodies is supposed to be generally preserved in all their combinations. Thus if A be *electro-negative* in respect of B and of C, B will generally be *electro-negative* in relation to C; but this appears not to be universally so, and sometimes one *electro-negative* body is found combined with two or more bases, and sometimes two acids are combined with a single base.

If, says Berzelius, with these theoretic notions in our mind we look through the productions of the Mineral kingdom, the apparently confused combinations which Minerals present will be immediately pervaded by regularity and order. We perceive an extensive class of Minerals into which siliceous enters as a constituent, assuming the character of salts, either simple, double, triple, or quadruple, and with various excesses of the *acid* or the *base*. In the same manner we perceive the oxides of titanium, of tellurium, and of other metals, performing the functions of acids, and thus reducing the whole series of Minerals to one uniform system of classification; and the doctrine of definite proportions introduced within a few years into Chemistry, might, if we could fully avail ourselves of its aid, be said to confer on this system of Mineralogical classification a degree of almost mathematical precision. But, as we have already stated, in consequence of the difficulty of ascertaining the proportions of the actual ingredients of Minerals, and the still greater difficulty of distinguishing those which are essential to the species analyzed, we are not yet enabled to confer on a chemical classification all the advantages offered by the improved doctrines of Chemistry.

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In the large class of Minerals containing siliceous, and which are the only ones that are likely to occasion much difficulty, we are persuaded that there are not at present sufficient data to determine their chemical species with accuracy. And in this opinion we have the concurrence of the author himself; for he allows in his *Nouveau Système Minéralogique*, at p. 22, that although the number of analyses already made by Klaproth, and others since his time, supply a large store of materials for the determination of species, yet the entire accomplishment of this object must be the result of future labours, directed sedulously and entirely to the accuracy of analysis. And in p. 92 of the same Work he says, "I cannot be certain that the analysis of the triple or quadruple silicates, or consequently the formulæ deduced from these, are correct. I give them only as examples of the *probable composition* of these Minerals. The art of analysis not being yet advanced to that degree of perfection, which will command our reliance on its results when the ingredients of the substance analyzed are numerous." It is on these grounds that we have omitted the Mineralogical formulæ of Berzelius in this Treatise.

We have, however, adopted provisionally his chemical classification, as it appears in the *Annals of Philosophy, New Series*, vol. xi. p. 422, being, we believe, the best natural arrangement yet proposed. To the list there given, the later examined Minerals have been added.

In this arrangement we have numbered the species, and in the alphabetical list we have given references to these numbers, by which the chemical order of the different species in that list may be readily ascertained.

We have also for the more convenient reference to cabinets which may be arranged according to this system, retained the different substances in the order there adopted by Berzelius, although in his recent Work on Chemistry that order has been a little varied.

#### Chemical Classification of Minerals.

- Iron, native, meteoric. *Aerolite*, 1.  
 terrestrial, 1. from France, 2.  
 ... 2. from North America, Connecticut, 3.  
 ... 3. Pennsylvania, 4.  
 volcanic, 5.  
 native steel? terrestrial, 6.  
 volcanic, 7.
- Copper, native, 8.  
*Bismuth*, native, 9.  
*Lead*, native, 10.  
*Silver*, native, 11.  
*Mercury*, native, 12.  
 Hydrarguret of silver. *Amalgam*, 13.  
*Palladium*, native, 14.  
*Platina*, native, 15.  
*Osmium*.  
 Osmiuret of *iridium*, 16.  
*Gold*, native, 17.  
 Aururet of silver. *Electrum*, 18.  
*Tellurium*, native, 19.  
 Telluret of bismuth, 20.  
 ... and silver, 21.  
 ... lead and silver. *Foliated?* 22.  
 ... and gold. *Yellow*, 23.  
 ... silver and gold. *Graphite*, 24.
- Antimony*, native, 25.  
 Stibiuret of silver. *Antimonial silver*, 26.



**Mineralogy Silica, quartz, 154. Varieties.**

**Hydrous quartz.** *Opal*, &c. 155.  
*Hydrosilicite*, 156.  
*Konilite*, 157.  
*Tripoli*, 158.

*Gryserite*, 159.

**a. Silicates with a single base.**

**Silicate of lime.** *From Aedelfors*, 160.  
*Wollastonite*, 161.  
*Okenite*, 162.  
*Serpentine*, 163.  
*Sieatite*, 164.  
*Ecume de mer*, 165.  
*Pyralloilite*, 166.  
*Marmolite*, 167.  
*Electric calamine*, 168.  
**zinc.** *Electric calamine*, 168.  
**manganese**, 169.  
**cerium, red.** *Cerite*, 170.  
**yellow**, 171.  
**iron.** *Hisingerite*, 172.  
*Chlorophæite*, 173.  
*Chloropal*, 174.  
*Sideroschisolite*, 175.  
*Thraulite*, 176.  
*Nontronite*, 177.  
**copper.** *Diopase*, 178.  
*Chrysocolle*, 179.  
**zirconia.** *Zircon*, 180.  
**alumina.** *Kyanite*, 181.  
*Sillimanite*, 182.  
*Bucholzite*, 183.  
*Fibrolite*, 184.  
*Andalusite*, 185.  
*Chiasolite*, 186.

**Hydrous silicates of alumina.**

*Pholerite*, 187.  
*Allophane*, 188.  
*Lenzinite*, 189.  
*Halloysite*, 190.  
*Severite*, 191.  
*Fuller's earth*, 192.  
*Cimolite*, 193.  
*Agalmatolite*, 194.  
*Lithomarge*, 195.  
*Bole*, 196.  
*Mountain soap*, 197.  
*Lemnian earth*, 198.  
*Kollyrite*, 199.  
*Scarbröite*, 200.  
*Kaolin*, 201.  
*Clay*, 202.  
*Ampelite*, 203.

**b. Silicates with several bases.**

1. An alkali, alumina, water.  
*Apophyllite*, 204.  
*Chabasie*, with base of soda, 205.  
*lime. Leryne*, 206.

*Mesotype*, 207.  
*Mesolite*, 208.  
*Mesole*, 209.  
*Analcime*, 210.  
*Gmelinite*, 211.  
*Thomsonite*, 212.  
*Stilbite*, 213.  
*Epistilbite*, 214.  
*Heulandite*, 215.  
*Brewsterite*, 216.

*Laumonite*, 217.  
*Skolezite*, 218.  
*Zeagonite*, 219.  
*Harmotome*, 220.  
*Edingtonite*, 221.  
*Prehnite*, 222.  
*Killinite*, 223.  
*Radiolite*, 224.  
2. An alkali, lime, and water.  
*Pektolite*, 225.  
3. An alkali, alumina, anhydrous.  
*Felspar*, 226.  
*Cleavelandite*, 227.  
*Anorthite*, 228.  
*Petalite*, 229.  
*Spodumene*, with *lithia*, 230.  
*with soda*, 231.  
*Gabbroite*, 232.  
*Leucite*, 233.  
*Labradorite*, 234.  
*Scapolite*, 235.  
*Meionite*, 236.  
*Ekebergite*, 237.  
*Fluolite*, 238.  
*Nepheline*, 239.  
*Sodalite*, 240.  
*Itnerite*, 241.  
*Anhydrous skolezite*, 242.  
*Erlanite*, 243.  
*Glaucolite*, 244.

**Appendix.**

*Pearlstone*, 245.  
*Pitchstone*, 246.  
*Pumice*, 247.  
*Sphaerulite*, 248.  
*Obsidian*, 249.  
*Lava*, 250.  
4. An alkali, magnesia, or oxide of iron, or of manganese.  
*Picrolite*, 251.  
*Picrosmine*, 252.  
*Pimelite*, 253.  
*Talc*, 254.  
*Pyrophyllite*, 255.  
*Chlorite*, 256.  
*Green earth*, 257.  
*Mica, rhomboidal*, 258.  
*oblique prisms*, 259.  
*Lepidolite*, 260.  
*Margarite*, 261.  
*Rubellan*, 262.  
*Oderit*, 263.  
*Gieseckite*, 264.  
*Fahlunite*, 265.  
*Pinite*, 266.  
5. An alkali, oxide of iron.  
*Achmite*, 267.  
6. Lime, magnesia, or oxide of iron, or manganese.  
The silica sometimes replaced by alumina.  
*Pyroxene*, 268.  
*white*, 269.  
*green*, 270.  
*Manganesian*, 271.  
*Augite*, 272.  
*Jeffersonite*, 273.  
*Bustamite*, 274.  
*Amphibole*, 275.

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- Grammatite*, 276.  
*Actynolite*, 277.  
*Hornblende*, 278.  
*Arfvedsonite*? 279.
7. Lime, magnesia, oxide of iron, oxide of manganese.  
*Ilvaite*, 280.  
*Cronstedtite*, 281.  
*Pyrosmalite*, 282.  
*Peridot*, 283.  
*Hyalosiderite*, 284.  
*Hypersthene*, 285.  
*Bronzite*, 286.  
*Schaller spar*, 287.  
*Knebelite*, 288.
8. Lime or magnesia, or oxide of iron or manganese or cerium, alumina.  
*Epidote*, 289.  
*Zoisite*, 290.  
*Idocrase*, 291.  
     magnesian. *Loboite*, 292.  
     cupriferous. *Cyprine*, 293.
- Garnet*, 294.  
     *Grosular*, 295.  
     *Aplome*, 296.  
     *Almandine*, 297.  
     *Magnesian*, 298.  
     *Manganesian*, 299.  
     *Pyrope*, 300.  
     *Esronite*, 301.
- Helvin*, 302.  
*Gehlenite*, 303.  
*Anthophyllite*, 304.  
*Dichroite*, 305.  
*Jade*, 306.  
*Nephrite*, 307.  
*Saussurite*, 308.  
*Sordawallite*, 309.  
*Isopyre*, 310.  
*Tachylite*? 311.  
*Karpholite*, 312.  
*Sapphirin*, 313.  
*Chamoussite*, 314.  
*Indianite*, 315.  
*Latrobeite*, 316.  
*Leelite*, 317.  
*Ligurite*, 318.  
*Cerine*, 319.  
*Allanite*, 320.
9. Oxide of iron, alumina  
*Staurotide*, 321.
10. Glucina, alumina.  
*Emerald*, 322.  
*Eucrase*, 323.  
*Chrysoberil*, 324.
11. Yttria, oxide of iron, oxide of cerium, &c.  
*Gadolinite*, from Ytterby, 325.  
     *Kararfoet*, 326.  
*Orthite*, 327.  
*Pyrothite*, 328.
12. Zirconia, oxide of iron, &c.  
*Eudyalite*, 329.
- Appendix to silicates. Minerals not analyzed, or of doubtful composition.  
*Auralite*, 330.  
*Amphodelite*, 331.  
*Babingtonite*, 332.

- Bergmannite*, 333.  
*Biotina*, 334.  
*Bovellite*, 335.  
*Bucklandite*, 336.  
*Cavolinite*, 337.  
*Cereolite*, 338.  
*Chusite*, 339.  
*Comptonite*, 340.  
*Davyne*, 341.  
*Desmine*, 342.  
*Dipyre*, 343.  
*Distrite*, 344.  
*Domite*, 345.  
*Forsterite*, 346.  
*Freisleben*, 347.  
*Fuscite*, 348.  
*Gigantolite*, 349.  
*Harringtonite*, 350.  
*Hedenbergite*, 351.  
*Herderite*, 352.  
*Herschellite*, 353.  
*Humite*, 354.  
*Iberite*, 355.  
*Ilmenite*, 356.  
*Green iron earth*, 357.  
*Keffikillite*, 358.  
*Lherzolite*, 359.  
*Limbite*, 360.  
*Mellilite*, 361.  
*Monticellite*, 362.  
*Murchisonite*, 363.  
*Necronite*, 364.  
*Nuttallite*, 365.  
*Osmelite*, 366.  
*Ostranite*, 367.  
*Pingute*, 368.  
*Poonahite*, 369.  
*Pyrrargillite*, 370.  
*Razoumoffskin*, 371.  
*Sarcolite*, 372.  
*Sideroclepte*, 373.  
*Somervillite*, 374.  
*Tautolite*, 375.  
*Thorite*, 376.  
*Torrelite*, 377.  
*Turnerite*, 378.  
*Vargasite*, 379.  
*Warthite*, 380.  
*Withamite*, 381.  
*Wolkonskoit*, 382.  
*Xanthite*, 383.  
*Xantholite*, 384.  
*Zurite*, 385.
- Oxide of titanium, (titanic acid.) *Anatase*, 386.  
*Rutile*, 387.  
*Brookite*? 388.
- Titaniate of iron. *Iron sand*, 389.  
*Nigrine*, 390.  
*Axotomous iron*, 391.  
*Crichtonite*, 392.  
*Mohsile*, 393.
- Silico-titaniate of lime. *Sphene*, 394.
- Titaniates with several bases of cerium yttria, zirconia, &c.  
*Pyrochlore*, 395.  
*Polymignite*, 396.  
*Eschynite*, 397.

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Mineralogy *Tantalic acid.*

Tantalates of yttria, cerium, iron, &c.  
*Fergusonite*, 398.

*Yttrotantalite*, black, 399.  
brown, 400.  
yellow, 401.

*Tantalite*, 402.

- a. from Kimito, 403.
- b. . . Finbo, 404.
- c. . . Brodbo, 405.
- d. . . Bavaria, 406.
- e. . . North America, 407.
- f. . . Kimito, giving a cinnamon-coloured powder, 408.

Oxide of antimony. *White antimony*, 409.

Oxi-sulphuret of antimony. *Red antimony*, 410.  
*Tinder ore*? 411.

*Scheelie acid*, 412.

Scheelite of lime. *Tungsten*, 413.

- ... iron and manganese. *Wolfram*, 414.
- ... lead, 415.

*Molybdic acid*, 416.

Molybdate of lead, 417.

*Pamplonite*? 418.

Oxide of chrome, native, 419.

Chromate of iron, 420.

... lead, 421.

... lead and copper, *Vauquelinite*, 422.

*Boracic acid*, hydrous, native, 423.

Borate of soda. *Tincal*, 424.

... magnesia. *Boracite*, 425.

Boro-silicate of lime. *Dalholite*, 426

*Humboldtite*, 427

*Botryolite*, 428.

... alumina, lime, &c.

*Tourmaline*, 429.

a with base of potash.

b ... lithia.

c ... magnesia.

*Azinite*, 430.

*Carbonic acid*, gaseous, native, 431.

Carbonate of soda. *Oblique rhombic prisms*, 432.

*right rhombic prisms*, 433.

*Trona*, 434.

*bi-carbonate*? 435.

... and lime. *Gay Lussite*, 436.

*Barrucite*, 437.

... barytes, 438.

... strontia, 439.

barytiferous. *Stromnite*, 440.

... lime, a. *Calcite*, 441.

b. *Arragonite*, 442.

... and barytes. *Barytocalcite*, 443.

... and iron. *Ankerite*, 444.

... and lead. *Plumbocalcite*, 445.

... magnesia, 446.

... and lime. *Bitter spar*, 447.

*Mesitine spar*? 448.

... and iron, 449.

... and iron, 450.

... manganese, 451.

... iron. *Brown spar*, 452.

*argillaceous*, clay-iron-stone, 453.

... zinc. *Calamine*, 454.

a. crystallized.

b. earthy.

... cerium, 455.

Carbonate of bismuth, 456.

*silicious*. *Bismuth blende*, 457.

... lead, 458.

... silver. *Selbite*, 459.

... copper, green. *Malachite*, 460.

blue, 461.

*silicious*. *Chrysocola* in part, 462.

*anhydrous*, 463.

... and zinc. *Kupferschaum*, 464.

Oxide of arsenic, *arsenic acid*, 465.

Arseniate of lime. *Pharmacolite*, 466.

*Haidingerite*, 467.

... iron, rhombic. *Scorodite*, 468.

cubic, 469.

*amorphous*? 470.

*arsenite*? 471.

... cobalt. *Red cobalt*, 472.

*Roselite*, 473.

... nickel, 474.

... lead. *Brown lead*, 475.

*Arsenite*? 476.

... copper. *Octahedral*, 477.

*Olivenite*, 478.

*Euchroite*, 479

*Tridrad* of Bournon, 480.

*Copper mica*, 481.

*Erinite*, 482.

*Condurrite*? 483.

*Vanadic acid*.

Vanadate of lead, 484.

*Phosphoric acid*.

Phosphate of lime. *Apatite*, 485.

... magnesia. *Wagnerite*, 486.

... yttria, 487.

... iron. *Vivianite*, 488.

*Karphosiderite*, 489.

... manganese and iron. *Pitch ore*, 490.

*Hetepozite*, 491.

*Huraulite*, 492.

... lead, 493.

*phosphato-arsenate*, 494.

... copper, *right rhombic*, 495.

*oblique rhombic*, 496.

... alumina. *Wavellite*, 497.

... and ammonia, *from the Isle of*

*Bourbon*, 498.

*Azurite*, 499.

*Calait*, 500.

*Amblygonite*, 501.

*Childrenite*, 502.

*Kakozene*, 503.

uranium. *Uranite*, 504.

*Chalkolite*, 505.

*Fluoric acid*.

Fluate of lime. *Fluor*, 506.

*fluo-arsenate of lime*, 507.

... yttria, 508.

... cerium, *neutral*, 509.

... sub-fluate, 510

... and yttria, 511.

... and lime. *Yttrocercite*, 512.

alumina. *Fluellite*, 513.

... and soda. *Cryolite*, 514.

Fluo-silicate of magnesia. *Condrodite*, 515.

alumina. *Topaz*, 516.

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*Mineralog.* **Nitric acid.**

Nitrate of potash, *Nitre*, 517.

... soda, 518.

... lime, 519.

... magnesia, 520.

**Sulphuric acid**, native, gaseous, 521.  
fluid, 522.

Sulphate of ammonia. *Muscagnine*, 523.

... potash, 524.

... soda. *Glauber salt*, 525.

*Anhydrous. Thenardite*, 526.

... barytes. *Baroselenite*, 527.

• *Baryto-fluoride?* 528.

*Schoarite?* 529.

... strontia. *Celestine*, 530.

... and barytes. *Grunerite*, 531.

... lime. *Gypsum*, 532.

*Anhydrite*, 533.

... and soda. *Glauberite*, 534.

... magnesia. *Epsomite*, 535.

... and soda. *Reussite*, 536.

*Bloedite*, 537.

... soda and lime. *Polyhallite*, 538.

... zinc, 539.

... iron. Green. *Melanterite*, 540.

... Red. *Botryogene*, 541.

... Fibrous, 542.

... Earthy. *Misy?* 543.

... copper. *Soluble*, 544.

*Insoluble? Brochantite*, 545

*Konigine*, 546.

... cobalt, 547.

... lead, 548.

... and copper, 549.

Sulphato-carbonate of lead, 550.

... and copper, 551.

... tri-carbonate of lead, 552.

... a. Rhomboidal, 553.

... b. Prismatic, 554.

Sulphate of alumina. Neutral, 555.

... with excess of base, 556.

... Websterite, 557.

... Davite, 558.

and potash. *Alum*, 559.

... uranium, 560.

... and copper. *Johannite*, 561.

Silico-sulphate of alumina. *Oldhamite*, 562.

... and potash. *Alum-stone*, 563.

**Silicates containing sulphates.**

*Lazulite*, 564.

*Hallite*, 565.

*Spinellene*, 566.

*Velvet copper*, 567.

**Appendix. • Metallic?**

*Breislakite*, 568.

*Pelokonite*, 569.

*Tephroite*, 570.

*Hopeite*, 571.

**Minerals apparently derived from organic substances.**

*Mould*, 572.

*Peat*, 573.

*Lignite. Wood coal*, 574.

*Dysodil. Paper coal*, 575.

*Amber*, 576.

*Retinasphaltum*, 577.

*Fossil copal*, 578.

*Hatchetine*, 579.

*Naphtha*, 580.

*Petroleum*, 581.

*Elastic bitumen*, 582.

*Earthy bitumen. Maltha*, 583.

*Murindo*, 584.

*Asphaltum*, 585.

*Bituminous coal*, 586.

*Native Naphthaline*, 587.

*Schererite*, 588.

*Xylocryptite*, 589.

*Mellite*, 590.

*Oxalate of iron*, 591.

(14.) It will readily be discovered by the reader, on looking through the preceding chemical classification, that if he desires to ascertain whether a particular Mineral which he sees for the first time is included in it, the order in which the species are there placed, even supposing them accompanied by their descriptions, does not enable him to do so. Some other arrangement, therefore, which for the sake of distinction we have termed artificial, is required for this purpose.

The first attempt at an arrangement of Minerals, with a view of affording the means of recognising them, is, we believe, contained in Aikin's *Manual of Mineralogy*, and is founded on the effects produced by the blowpipe, combined with some other characters. But serviceable as this arrangement might be, it is probable from the infrequency with which the blowpipe is used by Mineralogists, that it has not afforded the assistance it is capable of rendering.

(15.) The only other attempt at an artificial arrangement of Minerals, founded on their external and physical characters, for the purposes of identifying and distinguishing them, which has been published in this Country, is the system of Mohs; that of Weiss, by which it is said to have been preceded, not having to our knowledge been printed either here or in France. The system established by Mohs, although imperfect in respect to a particular class of crystalline forms, and defective in respect to the arrangement of many of the species, which are thrown into appendices to the several orders of the system, is said to have fulfilled in a very great degree the object for which it was framed, and to have enabled his pupils to determine Mineral species when first presented to them with a considerable degree of precision. The translation which has appeared in this Country, although made by a pupil of Mohs, eminently acquainted with his subject, and writing our language with great correctness, is yet not given in so perfect an English dress as to enable the reader at all times to comprehend fully the meaning of the author. The difficulty, however, which the reader might experience from this cause, is nothing in comparison with that which he has to encounter in the minute analysis of the principles of the system, its learned yet repulsive nomenclature, and the symbols which represent the crystalline forms. Indeed, so formidable have these characters of the Work appeared to Mineralogists in this Country, that we believe it has had very few, if any readers. We, however, give the following abstract of the system, stripped of its repulsive appendages.

Mineralogy

## SYSTEM OF MOHS.

## Class 1. Sp.gr. under 3.8.

No bituminous odour.

## Order 1. Sp.gr. 0.0001, 0.0014.

Gaseous.

Not acid.

## 2. Sp.gr. 1.0.

Liquid.

No odour or taste.

## 3. Sp.gr. 0.0015, 3.7.

Acid.

## 4. Sp.gr. 1.2, 2.9.

Solid.

Soluble in water.

Not acid.

## Class 2. Sp.gr. above 1.8.

Tasteless.

## Order 1. Non-metallic.

Streak uncoloured.

Hard. 1.5, 5.0.

Sp.gr. 2.2, 3.3.

a. Square or rhombic prisms; Hard. 4.0 or less; cleavage imperfect, oblique.

b. Cube; Hard. 4.0.

c. Single cleavage, bright; sp.gr. 2.4 or less.

d. Hard. under 2.5; sp.gr. 2.4 or less.

e. Hard. under 2.5; sp.gr. 2.4 or less; lustre not resinous.

## 2. Non-metallic.

Streak uncoloured, or orange yellow

Hard. 2.5, 5.0.

Sp.gr. 3.3, 7.3.

a. Single cleavage; sp.gr. 4.0 or less, 5.0 and more.

b. Lustre adamantine or imperfect metallic; sp.gr. 5.0 and more.

c. Streak orange-yellow; sp.gr. 6.0 and more.

d. Hard. 5.0; sp.gr. under 4.5.

e. Hard. 5.0; sp.gr. under 4.0; triple cleavage.

## 3. Non-metallic.

Streak uncoloured.

Cleavage not single, imperfect.

Hard. 1.0, 2.0.

Sp.gr. above 5.5.

## 4. Non-metallic.

Colour blue, green, brown.

Cleavage not single.

Hard. 2.0, 5.0.

Sp.gr. 2.0, 4.6.

a. Colour or streak brown; Hard. 3.0 or less; sp.gr. above 2.5.

b. Streak blue; Hard. 4.0 or less.

c. Streak uncoloured; Hard. under 3.0; sp.gr. 2.2 or less.

## 5. Cleavage single, bright.

Hard. 1.0, 4.5.

Sp.gr. 1.6, 3.2.

a. Metallic; sp.gr. under 2.2.

b. Non-metallic; sp.gr. above 2.2.

c. Rhomboid; Hard. 3.0 and more.

d. Metallic; sp.gr. under 2.5.

## 6. Non-metallic.

Streak uncoloured, brown, blue.

Hard. 3.5, 7.0.

## Class 2. continued.

## Order 6. continued.

Sp.gr. 2.0, 3.7.

a. Cube; sp.gr. 3.0 or less.

b. Rhomboid; Hard. 6.0; sp.gr. 2.2 or less.

c. Single cleavage, bright; Hard. 4.0 or less.

d. Lustre pearly; Hard. above 6.0; sp.gr. under 2.5, or above 2.8.

e. Lustre not adamantine; oblique rhombic, or doubly oblique prisms; Hard. 6.0; sp.gr. above 3.3.

f. Traces of form and cleavage; sp.gr. 2.4 or less.

## 7. Non-metallic.

No metallic adamantine lustre.

Streak uncoloured.

Hard. 5.5, 10.0.

Sp.gr. 1.9, 4.7.

a. Hard. 6.0, or less.

Cube; sp.gr. 3.0 and more.

No form or cleavage; sp.gr. 2.4 or less.

b. No pearly lustre, on cleavage planes; sp.gr. under 3.8.

## 8. No green streak.

Hard. 2.5, 7.0.

Sp.gr. 3.4, 7.4.

a. Metallic; colour black.

b. Non-metallic; lustre adamantine or imperfect metallic.

c. Streak yellow or red; Hard. 3.5 and more; sp.gr. 4.8 and more.

d. Streak brown or black; Hard. 5.0 and more; or single cleavage.

e. Streak yellow, red, or black; Hard. 4.5 or less.

f. Streak uncoloured; Hard. 6.5 and more; sp.gr. 6.5 and more.

## 9. Metallic.

Colour not black.

Hard. 0.0, 5.0.

Sp.gr. 5.7, 20.0.

a. Malleable, colour grey; sp.gr. 7.4 and more.

b. Malleable; Hard. above 4.0.

## 10. Metallic.

Hard. 3.0, 6.5.

Sp.gr. 4.1, 7.7.

a. Hard. 4.5 or less; sp.gr. under 5.3.

b. Colour yellow or red; sp.gr. 5.3 or less.

## 11. Metallic.

Colour grey, black.

Hard. 1.0, 4.0.

Sp.gr. 4.2, 7.6.

a. Colour lead-grey; single cleavage; sp.gr. under 5.0.

b. Colour lead-grey; sp.gr. above 7.4.

## 12. Streak green, brown, red, uncoloured.

Hard. 1.0, 4.0.

Sp.gr. 3.9, 8.2.

a. Metallic; colour black.

b. Non-metallic; lustre adamantine.

c. Streak green; colour black.

d. Streak brown, uncoloured; cube; sp.gr. 4.0, 4.2.

e. Streak red; Hard. 2.5 or less.

f. Streak red; sp.gr. 4.3 and more.

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Mineralogy Class 2. continued.

Order 13. Non-metallic.

Colour yellow, red, brown.

Rhombic prism.

Hard. 1.0, 2.5.

Sp.gr. 1.9, 3.6.

a. Single cleavage; sp.gr. 3.4 and more.

b. Streak yellow, red; sp.gr. above 2.1.

Class 3. Sp.gr. under 1.8.

a. Fluid; bituminous odour.

b. Solid; tasteless.

Order 1. Hard. 0.0, 2.5.

Sp.gr. 0.7, 1.6.

a. Streak uncoloured. sp.gr. 1.2 and more.

2. Streak brown, black.

Hard. 1.0, 2.5.

Sp. gr. 1.2, 1.5.

We recommend the reader, if he wishes to ascertain the real value of this arrangement, to attempt a classification of the Minerals he is acquainted with by the characters here given, and to compare his result with the order in which the several Minerals are placed in the translation we have referred to.

(16.) The very brief descriptions given in the following list are all that the space allotted to this Essay will allow, and we must refer the reader to Leonhard's *Handbuch der Oryctognosie*, for the results of Chemical analysis; to Haüy's *Traité de Minéralogie*, and to Phillips's *Elementary Introduction*, for figures and measurements of Crystals; and to the "observations" in Haidinger's translation of the system of Mohs, for much valuable Mineralogical information.

The alphabetical form we have given to our list, will be found convenient for reference. Although, however, the leading form of our list is alphabetical, it is also, with the exception of the compound silicates, chemically arranged according to the *bases*, by which order the ores of each metal are kept together. The reader has thus the two chemical classifications before him. That already given from Berzelius being arranged according to the *acids* with a particular view to the theory of isomorphism.

We have deemed it advisable to give single names to some of the species that before had only their chemical designation, as *Calcite* to Carbonate of lime. These names have generally been derived from places or persons, having observed that significant names derived from some property or character or theoretical view of the substances to which they have been applied, have frequently led to the mistakes of one substance for another, merely because the property from which the significant name was derived, happened to be common to both.

We observe, in looking at the late editions of Beudant's *Mineralogy* and Breithaupt's *Charakteristik*, that these authors also have felt the advantage of denoting Minerals by single names; but they have carried their alterations very much further than appears to be necessary, and they have too frequently followed the exceptionable examples before them, of employing a significant nomenclature.

We have deemed it sufficient to refer specially to the Works of Haüy, Phillips, Haidinger, and Leonhard, as the reader will find in these ample references to other authorities. But we have occasionally found it necessary to quote from other books.

The abbreviations used are the following.

Haüy. *Traité de Minéralogie*, second edition, 1822.

Phil. *Elementary Introduction to Mineralogy*, by W. Phillips, 1823.

Haid. *Treatise on Mineralogy*, by F. Mohs, translated by W. Haidinger, 1824.

Leon. *Handbuch der Oryctognosie*, by K. C. v. Leonhard, 1826.

B.M. *British Mineralogy*, by J. Sowerby.

N.J. Nicholson's *Journal*, 8vo.

P.M. *Philosophical Magazine*.

S.J. Silliman's *Journal*.

An. *Annals of Philosophy*.

An. n.s. *Annals of Philosophy, New Series*.

P.M. and An. *Philosophical Magazine and Annals*.

P.M. and J.S. *Philosophical Magazine and Journal of Science*.

E.P.J. *Edinburgh Philosophical Journal*.

E.P.J. n.s. *Edinburgh Philosophical Journal, New Series*.

E.J.S. *Edinburgh Journal of Science*.

E.J.S. n.s. *Edinburgh Journal of Science, New Series*.

Q.J.S. *Quarterly Journal of Science*.

Lucas. *Tableau des Espèces Minérales*, 1813.

Gal. *Recueil Minéralogiques par le Prince Dimitri de Gallizin*.

The Mineralogical student will find much useful matter in the Treatises on Mineralogy by Kirwan, Jameson, Aikin, Cleaveland, and those of later writers in France and Germany.

We have followed Mohs in the numbers which express the degree of hardness (Hard.) of Minerals, his scale being as follows.

- |                       |              |
|-----------------------|--------------|
| 1. Green talc.        | 6. Adularia. |
| 2. Gypsum.            | 7. Quartz.   |
| 3. Carbonate of lime. | 8. Topaz.    |
| 4. Fluorspar.         | 9. Corundum. |
| 5. Apatite.           | 10. Diamond. |

But we are persuaded that this character requires to be much more accurately ascertained than it has hitherto been, and by a more strict method of comparison than merely passing a knife or file over the substance, and estimating its hardness by the degree of resistance it appears to offer.

ALPHABETICAL LIST OF MINERALS.

ACHMITE. *Euchysiderite*. No. 267.

Haid. 3.67. Leon. 513.

Has the form, cleavage, and measurement of Pyroxene. Hard. 6.0, 6.5. Sp.gr. 3.24. Nearly opaque. Lustre vitreous. Colour brownish-black. Streak yellowish-grey.

Found at Eger in Norway.

ALUMINA.

*Fluate of Alumina*.

a. FLUELLITE. No. 513.

Sowerby, *Brit. Min.* 3.83. 1807. An. 8.242. Haid. 3.101. Leon. 739.

Occurs in attached octahedral crystals.

Primary form, a Right rhombic prism. Cryst. fig.

71. M.M. = 105°. Transparent. Colour white.

Found at Stenna Gwyn, Cornwall.

*Hydrate of Alumina*.

a. DIASPORE. No. 153.

Haüy, 2.163. Phil. 78. Haid. 3.92. Leon. 228.

Occurs in amorphous masses, with a thin columnar structure, the crystals crossing in every direction.

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Primary form, according to Phillips, a Doubly oblique prism. *CRYST.* fig. 95.  $P, M = 108^\circ 30'$ .  $P, T = 101^\circ 20'$ .  $M, T = 64^\circ 54'$ . *Sp.gr.* 3.43. Slightly translucent. Lustre vitreous. Colour slightly greenish-grey, and yellowish-brown.

Locality unknown, but supposed to have come from the Uralian mountains.

## b. GIBBSITE. No. 152.

Phil. 79. Haid. 3. 103. Leon. 740.

Occurs in irregular stalactitical and tuberculated masses. Structure fibrous, radiating. Hard. 3.0, 3.5. *Sp.gr.* 2.4. Slightly translucent. Nearly dull. Colour greenish or greyish-white. Streak white.

Found at Richmond, Massachusetts, North America.

c. CALAITE. *Agaphite. Johnite.*

*Mineral Turquoise.* No. 500.

Häuy, 4.516. Phil. 79. Haid. 3.83. Leon. 135.

Occurs in reniform nodules and amorphous masses, and in thin veins. Structure compact. Fracture conchoidal. Hard. 6.0. *Sp.gr.* 2.8, 3.2. Opaque. Colour sky-blue and bluish-green. Streak white.

Found in alluvial clay and in trap rock in Khorasan in Persia.

*Mellate of Alumina.*a. MELLITE. *Honey stone.* No. 590.

Häuy, 4.445. Phil. 374. Haid. 3.56. Leon. 790.

Occurs in attached and imbedded crystals, and small imbedded nodules or grains.

Primary form a Square prism. *CRYST.* fig. 65. Cleavage very indistinct parallel to the planes *a*, fig. 66. Fracture conchoidal. Hard. 2.0, 2.5. *Sp.gr.* 1.597. Transparent, translucent. Lustre vitreous-resinous. Colour honey-yellow, sometimes reddish or brownish. Streak white.

Found attached to and imbedded in bituminous wood, principally at Artern in Thuringia.

*Native Alumina.*

## a. CORUNDUM.

The blue transparent varieties are the Sapphire; the red, oriental Ruby; the purple, oriental Amethyst; the yellow, oriental Topaz; the opaque, adamantinite spar; the granular, Emery. No. 145.

Häuy, 2.70. Phil. 74. Haid. 2.199. Leon. 535. 538. Occurs in imbedded crystals and massive.

Primary form a Rhomboid. *CRYST.* fig. 106.  $P, P' = 86^\circ 4'$ . Cleavage parallel to *P*, and perpendicular to the axis. Fracture uneven. Hard. 9.0. *Sp.gr.* 3.91, 3.98. Transparent, translucent, opaque. Lustre vitreous. Colour white, grey, blue, green, yellow, red, brown. Streak white.

*Massive varieties*, amorphous. Structure perfectly crystalline, or granular and compact with a splintery fracture.

Found in India, China, North America, in Europe chiefly at St. Gothard and in Piedmont.

*Alumina, with silica and carbon.*

## a. ROTTEN STONE. No. 146.

Phil. 50.

Occurs massive. Fracture uneven. Soft, fine earthy, soils the fingers. Opaque. Dull. Colour greyish, reddish, and blackish-brown. Fetid when rubbed or scraped.

Found near Bakewell in Derbyshire, and at Albany near New York.

*Phosphate of Alumina.*a. WATHELLITE. *Elastonite.* No. 497

Häuy, 2.161. Phil. 146. Haid. 3.169. Leon. 133. Mineralogy

Occurs in globular concretions, formed of slender crystals radiating from the centre of the globules, with imperfect terminations, producing a drusy surface. Primary form of the crystals a Right rhombic prism. *CRYST.* fig. 71.  $M, M' = 122^\circ 15'$ . Cleavage parallel to the lateral planes, and the greater diagonal of the prism. Hard. 3.5, 4.0. *Sp.gr.* 2.3, 2.7. Translucent. Lustre vitreous, sometimes pearly on the cleavage planes. Colour nearly white, grey, brown, yellow, green, of various shades. Found near Barnstaple, in Devonshire; very rarely near St. Austle, Cornwall; in Ireland, Germany, and Brazil.

*Phosphate of Alumina and Ammonia.*

## a. MAURITCITE. No. 498.

An. de Ch. 21.188. Leon. 783.

A white earthy substance from the Isle of France, differing from the preceding Phosphate in the proportions of its constituent parts.

*Silicate of Alumina.*a. KYANITE. *Cyanite. Disthene. Rhatizite.* No. 181.

Häuy, 2.357. Phil. 81. Haid. 2.213. Leon. 406.

Occurs in columnar imbedded crystals and massive.

Primary form a Doubly oblique prism,  $P, M = 93^\circ 15'$ .  $P, T = 100^\circ 50'$ .  $M, T = 106^\circ 15'$ . Cleavage parallel to *T* very distinct; less so parallel to *M*; parallel to *P* indistinct. Fracture uneven. Hard. 5.0 on plane *T*, 7.0 on the edges and solid angles. *Sp.gr.* 3.6, 3.675. Transparent, translucent. Lustre vitreous, pearly on *T*. Colour white, bluish-grey, blue, pale bluish-green, yellow. Streak white.

*Massive varieties.* Aggregation of crystals promiscuously intersecting each other, sometimes very long, and occasionally so short and small as to appear large granular.

Found at St. Gothard in large crystals, in Scotland, and many other parts of Europe, and in North and South America.

## b. SILLIMANITE, No. 182.

Haid. 3.153. Leon. 409

Occurs in imbedded columnar rhombic prisms, of about  $106^\circ 30'$ . Haid.

Cleavage parallel to the long diagonal. Fracture splintery. Hard. 8.0, 8.5. *Sp.gr.* 3.41. Nearly opaque. Lustre, on the cleavage plane nearly adamantinite. Colour dark brownish-grey.

Found at Saybrook, Connecticut, North America. It approaches very nearly to Kyanite in its form and composition.

## c. BUCHOLZITE, No. 183.

Phil. 109. Leon. 409.

A fibrous substance from the Tyrol analyzed by Brandes. It is described as amorphous. Cross fracture imperfectly conchoidal. Hard. about 6.0. Slightly translucent. Lustre resinous. Colour yellowish and greyish-white.

One or two other fibrous Minerals apparently different from this have passed under this name. The composition of the substance analyzed by Brandes is nearly the same as that of Kyanite, and it may have been a fibrous variety of that Mineral.

## d. FIBROLITE, No. 184.

Phil. 80. Haid. 399. Leon.

Occurs in small fibrous masses. Hard. 7.5. *Sp.gr.* 3.214. Translucent, colour greyish-white.

Found in India and China accompanying Corundum.

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Fibrous varieties of Epidote, Kyanite, and other substances have passed under this name, and the composition of Bournon's Fibrolite is very nearly the same as that of Kyanite.

c. ANDALUSITE, No. 185.

Haid., 4.486. Phil. 108. Haid. 2.293. Leon. 404.

Primary form a Right rhombic prism.  $M, M' = 90^\circ 40'$ , measured on a transparent variety from North America. Cleavage parallel  $MM'$ . Fracture uneven, conchoidal. Hard. 7.5. Sp.gr. 3.104. Transparent to opaque. Lustre vitreous. Colour flesh-red to brownish and greyish-red.

Found generally in mica slate in Spain, France, and other parts of Europe, and lately in North America, in partially transparent crystals imbedded in quartz.

*Hydrous silicates of alumina. A very uncertain series, several of which are, probably, only accidental mixtures in variable and indefinite proportions.*

a. PHOLARITE, No. 187.

E.J.S. 6.364. Leon. 767.

Occurs in small, convex, nacreous scales.

Soft, friable. Colour white. Adheres to the tongue. Found in the coal formations of Fins, Department Allier, France.

b. ALLOPHANE, No. 188.

Phil. 88. Haid. 3.69. Leon. 183.

Occurs in globular, reniform, and botryoidal masses. No cleavage. Fracture conchoidal. Hard. nearly 3.0. Sp.gr. 1.85. Transparent, translucent. Lustre vitreous. Colour blue, green, brown, of several shades.

Found in limestone in Thuringia, at Schneeberg in Saxony, and probably in Derbyshire.

Some specimens, received in this Country under the name of Allophane, may be cleaved parallel to the planes of a rectangular solid, and are probably another Mineral.

c. LENZINITE. *Wallerite*, No. 189.

Phil. 87. Leon. 179.

Occurs in compact and earthy masses of various sizes. Compact. Fracture conchoidal. Hard. 1.5. Sp.gr. 2.10. Transparent on the edges. Nearly dull. Colour yellowish milk-white. Streak shining. Feels rather greasy. In water it separates with noise into small fragments.

*Earthy.* Fracture earthy. Soft. Sp.gr. 1.80. Slightly translucent, opaque. Dull. Colour snow-white. Streak shining.

Found at Kall in Eifel.

d. HALLOYSITE, No. 190.

E.J.S. 6. 183.

Occurs in nodular masses. Structure compact. Fracture conchoidal. Nearly opaque. Lustre waxy. Colour bluish and greyish-white. Streak shining. Adheres to the tongue.

Found in the neighbourhood of Liege and Namur. The analysis of this substance corresponds so nearly with that of Lenzinite as to leave little doubt of its being the same Mineral, but of a different colour.

e. SEVERITE, No. 191.

Phil. 87.

Occurs in small masses, nearly resembling Lithomarge. Fracture uneven. Hard. 1.0, 1.5. Slightly translucent. Dull. Colour white. Streak shining.

Found near St. Sever in France.

f. FULLER'S EARTH, No. 192.

Phil. 52. Haid. 3.182.

Occurs massive in beds of considerable thickness.

Fracture uneven, earthy. Soft. Sp.gr. 1.3, 2.2. Opaque. Dull. Colour greenish-brown, dull grey-white. Streak shining. Feels greasy.

Found in England, principally at Nutfield in Surrey, and in Stiria, Saxony, and some other places in Europe.

g. CIMOLITE, No. 193.

Phil. 54. Leon. 729.

Occurs in amorphous earthy masses, structure rather slaty. Fracture uneven, earthy. Soft. Sp.gr. 2.0. Opaque. Colour greyish-white.

Found in the Island of Cimola, near Argentaria. Used for the same purposes to which Fuller's earth is applied.

h. AGALMATOLITE. *Bildstein. Lardite. Pagodite.* No. 194.

Phil. 119. Haid. 3.100. Leon. 188.

Occurs massive. Fracture coarse, splintery. Soft. Sp.gr. 2.8. Slightly translucent. Colour white to brown, rather pale and dull. Streak shining. Unctuous to the touch.

Found in China, Transylvania, Saxony, and in Wales. Cut into various figures by the Chinese, and seldom brought to this Country in any other state.

i. LITHOMARGE. *Steinmark*, No. 195.

Haid., 4.558. Phil. 52. Haid. 3.183. Leon. 186.

Occurs massive. Spheroidal. Structure compact. Fracture large, conchoidal. Soft. Sp.gr. 2.2, 2.5. Opaque. Dull. Colour white, grey, red, yellow, blue. Streak shining. Adheres to the tongue. Unctuous to the touch.

Found in Saxony, and some other parts of Europe.

A friable variety is found at Ehrenfrudendorf in Saxony.

k. BOLE, No. 196.

Phil. 53. Haid. 3.179. Leon. 191.

Occurs massive. Structure compact. Fracture conchoidal. Soft. Sp.gr. 1.4, 2.0. Nearly opaque. Nearly dull. Colour brownish-black, red, yellow. Streak shining. Feels greasy. Adheres to the tongue.

Found in many places in trap rocks.

Several very different substances appear to have passed under this name, and it is doubtful if any one of them is correctly represented by the preceding description, yet we give it upon the authorities quoted.

l. MOUNTAIN SOAP, No. 197.

Phil. 53. Haid. 3.184. Leon. 192.

Occurs massive. Structure compact. Fracture fine earthy. Sectile. Opaque. Dull. Colour light brownish-black. Streak shining.

Found at Olkner in Poland.

m. LEMNIAN EARTH. *Terra sigillata*, No. 198.

Phil. 54. Leon. 191.

Occurs massive in the Isle of Lemnos. Fracture earthy. Soft. Opaque. Dull. Colour dull yellowish-grey and greyish-white.

An uncertain species.

n. KOLLYRITE, No. 199.

Phil. 88. Leon. 752.

Occurs massive, appearing like a tenacious white clay. When dry it splits into columnar masses like starch.

Found at Weissenfels in Thuringia.

The siliciferous Hydrate of Alumina, found in the

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Pyrenees and analyzed by Berthier, probably belongs to this species.

**c. STARRBRÜITE, No. 203.**

P.M. and An. 5. 178.

Occurs as veins in the beds of sandstone covering the calcareous rock at Scarborough.

Fracture conchoidal. Hard. about 2.0. Sp.gr. about 1.48. Opaque. Dull. Colour white. Streak shining. Adheres to the tongue. Strong earthy smell when breathed upon. Does not become translucent, nor fall to pieces in water.

**p. KAOLIN. Porcelain Clay, No. 201.**

Phil. 31. Leon. 185.

Occurs massive and disseminated in decomposed granite rocks. Fracture fine earthy. Soft. Sp.gr. 2.2. Opaque. Dull. Colour yellowish and reddish-white. Found in France, near Limoges and near Bayonne, and in Saxony, England, China, and other places.

**q. CLAY, No. 202.**

Phil. 55.56. Haid. 3. 180.

Occurs massive. Structure earthy. Fracture uneven. Soft. Sp. gr. 1.8, 2.8. Opaque. Dull. Colour white, grey, brown, red, yellow, &c., of various shades, and striped, spotted, &c. Streak shining. Found in all parts of the world.

The *Claystones* and *Slates* usually introduced into Catalogues of Minerals, appear too variable in their composition to admit of any distinct classification, and belong more properly to the geological series of rocks.

*Siliceiferous Sulphate of Alumina.*

**(OLDHAMITE, No. 562.**

An. 11.434.

Massive, and of the consistency of hog's-lard. Translucent. Colour, snow and milk-white. Taste, sub-acid. When exposed to the air, it dries and splits into long thin masses like starch, some of which are translucent and resemble gum arabic.

Found in a coal mine near Oldham in Lancashire.

*Sulphate of Alumina.*

**a. WEBSTERITE. Hallite, No. 557.**

Phil. 145. Haid. 3.70. Leon. 130.

Occurs in roundish or reniform masses, generally small. Fracture earthy. Soft, friable. Sp.gr. 1.7. Occasionally translucent, generally opaque. Colour white, sometimes yellowish. Streak white.

Found at Halle, in Prussia, in clay, and at Newhaven, Sussex, in limestone.

**b. DAVITE, No. 558.**

Q.J. n.s. 3.382. Leon. 433

Occurs massive. Structure fine fibrous. Lustre silky. Colour white. Taste highly astringent. Very soluble.

Found near a warm spring which contains sulphuric acid, near Bogota, in Columbia.

*Sulphate of Alumina and Potash.*

**a. ALUM, No. 559.**

Haüy, 2.114. Phil. 196. Haid. 2.50. Leon. 107.

Occurs as an efflorescence, and sometimes in stalactites and fibrous masses.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron, indistinct. Fracture conchoidal. Hard. 2.0, 2.5. Sp.gr. 1.75. Transparent, translucent. Lustre vitreous. Colour yellowish or greyish-white. Streak white. Taste astringent, sweetish.

Found in many parts of Europe.

**b. ALUM-STONE. Toffaite, No. 563.**

Haüy, 2.128. Phil. 196. Haid. 2.67. Leon. 131.

Occurs in attached crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106. P.P' = 92° 50'. Cleavage parallel to the primary planes, and more distinctly perpendicular to the axis. Fracture uneven. Hard. 5.0. Sp.gr. 2.7. Transparent, translucent. Lustre vitreous. Colour pale greyish and reddish-white. Streak white.

Massive varieties, amorphous, structure granular, compact.

Found at Tolfa, near Rome, in Tuscany, Naples, Hungary, and occasionally in the neighbourhood of active volcanoes.

**AMBYGONITE, No. 501.**

Phil. 198. Haid. 3.70. Leon. 283.

Occurs massive.

Cleavage parallel to the lateral planes of a rhombic prism of about 105° 45', and indistinctly oblique to its axis. Fracture uneven. Hard. 6.0. Sp.gr. 3.04. Translucent. Lustre vitreous, inclining to pearly. Colour greenish-white. Streak white.

Found near Chursdorf in Saxony, in Granite, accompanying Tourmaline and Topaz.

*AMMONIA.*

*Muriate of Ammonia.*

**a. SAL AMMONIAC, No. 60.**

Haüy, 2.221. Phil. 194. Haid. 2.30. Leon. 587.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the octahedron. Fracture conchoidal. Hard. 1.5, 2. Sp.gr. 1.528. Transparent to opaque. Colour white, grey, greenish, yellowish, and brownish. Lustre vitreous. Taste saline and pungent.

Massive varieties, stalactitic, botryoidal and reniform, with a fibrous structure, and occasionally in crusts. Found in the neighbourhood of active volcanoes, and occasionally in other situations. It sometimes occurs in the beds of coal near Newcastle.

*Sulphate of Ammonia.*

**a. MASCAGNIN, No. 523.**

Phil. 191. Haid. 3.125. Leon. 127.

Stalactitic and efflorescent. Semitransparent to opaque. Colour yellow and yellowish-grey. Taste acid, bitter.

Found in the neighbourhood of volcanoes.

**AMPHIBOLE, consisting of the following varieties:—**

*Common Hornblende*, colour dark green or greenish-black.

*Basaltic Hornblende.*

*Foliated Augite* of Werner.

*Blue Hyperstene* of Giesecke.

*Green Diallage* of Haüy; *Smaragdite*.

*Pargasite* in short green crystals.

*Actynolite*; the crystals green, slender, and sometimes radiating.

*Tremolite*; *Calamite*; *Grammatite*; colourless or green, or pink, or brownish-grey, generally imbedded in dolomite, frequently fibrous, and sometimes radiating.

*Amianthoide*; *Hyssolite*.

*Amianthus. Asbestos.* No. 275 to 278.

Haüy, 2.372. 454. 481. Phil. 63. 71. Haid. 2.27. Leon. 493.

Mineralogy

Mineralogy

Primary form an Oblique rhombic prism.  $P, M = 103^\circ 13'$ ,  $M, M' = 124^\circ 30'$ . Cleavage parallel to  $MM'$ , and less distinctly to the planes of modification  $h$  and  $k$ . Fracture uneven. Hard. 5.0, 6.0. Sp.gr. 2.93 to 3.2, or according to Phil. 3.6. Transparent to opaque. Lustre vitreous, sometimes pearly. Colour white to black. Streak greyish.

*Massive varieties* differ considerably in structure; from slaty to columnar and fibrous; the fibres sometimes, as in amianthus, being silky and flexible.

Found in all parts of the world, and in various geological positions.

**AMPELITE.** *Black Chalk*, No. 203.

Phil. 55. Haid. 3.181.

Occurs massive. Structure fine granular, slaty. Fracture fine earthy. Soft. Sp.gr. 2.11, 2.18. Opaque. Dull. Colour black. Streak rather shining.

Found in several parts of Europe in rocks of clay-slate.

**ANALCIME.** *Cubicite*, No. 210.

Haidy, 3.170. Phil. 129. Haid. 2.227. Leon. 202.

Occurs in attached and imbedded crystals. Primary form a Cube. Cryst. fig. 56. Cleavage parallel to  $P$  indistinct, interrupted. Fracture uneven. Hard. 5.5. Sp.gr. 2.068. Transparent to translucent. Lustre vitreous. Colour white, sometimes greyish and reddish. Streak white.

Found in several parts of Scotland, and in many different places in other Countries, chiefly in basaltic and amygdaloidal rocks.

**ANORTHITE**, No. 228.

Haid. 3.71. Leon. 432.

Occurs in attached crystals.

Primary form a Doubly oblique prism. Cryst. fig. 95.  $P, M = 94^\circ$ ;  $P, T = 110^\circ 50'$ ;  $M, T = 117^\circ 42'$ . Cleavage parallel to  $P$  and  $T$ . Fracture conchoidal. Hard. 6. Sp.gr. 2.76. Transparent to translucent. Lustre vitreous, and on  $P$  and  $T$  rather pearly. Colour white. Streak white.

Found in cavities in masses of Limestone, ejected from Vesuvius.

**ANTHOPHYLLITE**, No. 304.

Haidy, 2.600. Phil. 69. Haid. 2.211. Leon. 514. 432.

Occurs in crystalline masses, with a fibrous columnar structure.

Cleavage parallel to the lateral planes of a Rhombic prism of  $125^\circ$ , and to both its diagonals, the bright plane being parallel to the greater diagonal, and another imperfect cleavage transverse, and apparently perpendicular to the axis of the prism.

Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 3.2, 3.3. Translucent. Lustre pearly, and inclining to Metallic. Colour yellowish-brown. Streak white.

Found in beds of mica slate at Kongsberg and Modum in Norway.

#### ANTIMONY.

*Arsenurett of Antimony?*

**a. ARSENICAL ANTIMONY**, No. 38.

Leon. 719.

Occurs in botryoidal forms. Structure scaly. Fracture granular. Sp.gr. 6.2. Opaque. Dull. Colour tin-white.

Found at Przibram in Bohemia.

#### Native Antimony.

**NATIVE ANTIMONY**, No. 25.

Haidy, 4.79. Phil. 329. Haid. 2.426. Leon. 684.

Occurs in reniform or amorphous masses, with a granular structure, the grains being crystalline and differing considerably in size.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 117^\circ 15'$ , as inferred from cleavage, no regular crystals having yet been observed. Hard. 3.0, 3.5. Sp.gr. 6.646. Opaque. Lustre metallic. Colour tin-white. Streak the same.

Found in veins traversing ancient rocks, at Sahlberg in Sweden, at Allemont in Dauphiny, and at Andreasberg in the Hartz.

The arseniferous native antimony appears to be an accidental mixture of arsenic with native antimony.

#### Oxide of Antimony.

**a. WHITE ANTIMONY**, No. 409.

Haidy, 4.308. Phil. 331. Haid. 2.251. Leon. 335.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 136^\circ 58'$ . Cleavage parallel to  $M, M'$ . Lustre adamantine. Fracture indistinct. Hard. 2.5, 3.0. Sp.gr. 5.566. Translucent. Colour white, sometimes reddish or greyish. Streak white.

*Massive variety*, earthy, investing sulphuret and native antimony, and apparently produced by the decomposition of those Minerals.

Found in Bohemia, Saxony, Hungary, and France.

#### Sulphuret of Antimony.

**a. GREY ANTIMONY**, No. 93.

Haidy, 4.291. Phil. 329. Haid. 3. 23. Leon. 605.

Occurs in attached and aggregated crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 90^\circ 45'$ . The crystals sometimes capillary and flexible, like silky fibres. Cleavage parallel to diagonal of the prism. Fracture uneven. Hard. 2.0. Sp.gr. 4.62. Opaque. Lustre metallic. Colour between lead and steel-grey, frequently with a yellow and blue tarnish. Streak the same.

*Massive varieties*, amorphous, structure large fibrous, foliated, compact.

Found in Hungary, France, England, Scotland, the Hartz, Saxony, and other places.

**b. BLACK ANTIMONY**, No. 94.

Leon. 719.

Occurs as a black powder in cavities in Hornstone.

Found at Joachimsthal in Bohemia.

#### Sulphuret of Antimony and Nickel.

**a. HARTMANNITE**, No. 96.

Haid. 3.131. Leon. 615.

Occurs in imbedded crystalline particles and masses.

Primary form, according to Haidinger, a Cube. Cryst. fig. 56. Cleavage parallel to  $P$ . Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 6.451. Opaque. Lustre metallic. Colour whitish steel-grey. Streak the same.

*Massive variety*, amorphous. Structure granular.

Found in the Principality of Nassau.

#### Sulphuret of Antimony, Lead, and Iron.

**a. JAMESONITE**, No. 101.

Haid. 3.26. Leon. 748.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 101^\circ 20'$  nearly. Haid. Cleavage

Mineralogy

Mineralogy

parallel to P distinct, less so parallel to M. Fracture very indistinct. Hard. 2.0, 2.5. Sp.gr. 5.564. Opaque. Lustre metallic. Colour steel-grey, sometimes dark. Streak the same.

*Massive variety*, amorphous. Structure large to small fibrous.

Found in Cornwall and in Hungary, and probably in other places, where it has been considered a sulphuret of antimony.

*Sulphuret of Antimony and Lead.*

a. ZINKENITE, No. 99.

E.J.S. 6.17, 358.

Occurs in attached crystals, said to be regular hexagonal prisms, and massive.

Primary form a Rhomboid. Cryst. fig. 106. P, P' uncertain. No cleavage. Fracture uneven. Hard. 3.0, 3.5. Sp.gr. 5.303. Opaque. Lustre metallic, bright. Colour steel-grey. Streak the same. Found at Wolfsberg in the Hartz.

*Sulphuret of Antimony and Iron.*

a. BERTHIERITE, No. 102.

E.J.S. 7.353.

Occurs in confused laminated masses, or elongated imbedded prisms, resembling grey antimony. Colour dark steel-grey inclining to brown.

Found at Chazelles in Auvergne.

*Oxi-sulphuret of Antimony.*

a. RED ANTIMONY, No. 410.

Haüy, 4.311. Phil. 331. Haid. 3.36. Leon. 608.

Occurs in thin, acicular crystals, generally radiating, sometimes promiscuously aggregated.

Primary form, according to Phillips, a Square prism, and according to Haidinger an oblique rhombic prism. One bright cleavage, and others less distinct. Hard. 1.0, 1.5. Sp.gr. 4.5. Translucent. Lustre adamantine. Colour dull red.

Found at Braunsdorff in Saxony, in Hungary, France, and in the Hartz.

APLONE, No. 296.

Haüy, 2.538. Phil. 29. Haid. 2.364. Leon. 491.

Occurs in attached and imbedded dodecahedral crystals.

Primary form a Cube. Cryst. fig. 56. Surfaces of the Dodecahedron striated parallel to the edges of P. Cleavage imperfect parallel to P. Fracture uneven. Hard. 7.0, 7.5. Sp.gr. 3.444. Translucent, opaque. Lustre vitreo-resinous. Colour yellowish-brown.

Found in Saxony, Bohemia, Siberia, and in small crystals in England.

APOPHYLLITE. *Albin. Ichthyophthalmite. Tesselite. Oxahverite*, No. 204.

Haüy, 3.191. Phil. 110. Haid. 2.245. Leon. 213.

Occurs in attached crystals and massive.

Primary form a Square prism. Cryst. fig. 65.  $M, a = 109^\circ 40'$ . Cleavage parallel to P, perfect; less so parallel to M. Fracture uneven. Hard. 4.5, 5.0. Sp.gr. 2.46. Transparent, translucent. Lustre vitreous. Colour white, occasionally with a yellowish, greenish, or reddish tinge. Streak white.

*Massive variety*, amorphous, structure laminar.

Found in the cavities of trap rocks, and occasionally in beds of the older formations, in the Faroe Islands, in India, Sweden, Norway, the Bromart, Bohemia, and some other places. The Oxahverite from Oxahver in Iceland.

ARFVEDSONITE, No. 279.

Phil. 377. Haid. 3.73. Leon. 497.

Occurs massive amorphous. No crystalline form observed.

Cleavage parallel to the lateral planes, and both the diagonals of a Rhombic prism of  $123^\circ 53'$ . Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 3.44. Opaque. Lustre vitreous. Colour black.

Found in Norway, and in Greenland associated with Sodalite.

## ARSENIC.

*Native Arsenic.*

a. NATIVE ARSENIC, No. 27.

Haüy, 4.236. Phil. 275. Haid. 2.423. Leon. 676.

Occurs in reniform stalactitic and amorphous masses, frequently in parallel layers. Structure fine granular. Fracture uneven. Hard. 3.5. Sp.gr. 5.766. Opaque. Colour of fresh fracture greyish-tin-white, which afterwards becomes greyish-black. Streak shining.

Found in several parts of Saxony, in Bohemia, the Hartz, France, Norway, Transylvania, and other places; generally in metallic veins.

*Oxide of Arsenic.*

a. OXIDE OF ARSENIC, No. 465.

Haüy, 4.241. Phil. 375. Haid. 2.26. Leon. 333. 170.

Occurs in attached octahedral crystals and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the octahedron. Fracture conchoidal. Sp.gr. 3.7. Translucent, opaque. Lustre nearly adamantine. Colour white, occasionally yellowish. Streak white. Taste sweetish astringent.

*Massive varieties*, reniform, botryoidal, stalactitic, and amorphous.

Found accompanying native arsenic in many mineral veins, and produced from the decomposition of other Minerals. Is soluble in water and a violent poison.

*Red Sulphuret of Arsenic.*

a. REALGAR, No. 108.

Haüy, 4.247. Phil. 277. Haid. 3.49. Leon. 602.

Occurs in attached crystals and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 104^\circ 6'$ ,  $M, M' = 74^\circ 15'$ . Cleavage parallel to P and M. Fracture conchoidal. Hard. 1.5, 2.0. Sp.gr. 3.556. Transparent, opaque. Lustre resinous. Colour red. Streak orange-yellow.

*Massive varieties*, amorphous, structure granular.

Found principally in Hungary and Transylvania, also in Saxony, Bohemia, and some other places.

*Yellow Sulphuret of Arsenic.*

a. ORPIMENT, No. 109.

Haüy, 4.247. Phil. 277. Haid. 3.47. Leon. 599.

Occurs in imbedded imperfect crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 100^\circ$ . Cleavage parallel to the greater diagonal of the prism. Fracture uncertain. Hard. 1.5, 2.0. Sp.gr. 3.480. Translucent. Lustre resinous. Colour yellow. Streak paler yellow.

*Massive varieties*, botryoidal, reniform, nodular, sometimes granular, the structure of the grains or masses foliated, and the laminae very flexible.

Found in most of the districts which yield the red sulphuret, and is like that used as a pigment.

Mineralogy

**Mineralogy AURALITE, No. 330.**

Occurs in apparently hexagonal prisms in felspar at Abo in Finland. Opaque. Colour dark brown.

**AXINITE. Thumite. Yanolite, No. 430.**

Haüy, 2.559. Phil. 43. Haid. 2.341. Leon. 454. Occurs in attached and imbedded crystals, and massive.

Primary form a Doubly oblique prism. Cryst. fig. 95.  $P, M = 134^\circ 40'$ .  $P, T = 115^\circ 17'$ .  $M, T = 135^\circ 10'$ . Fracture uneven. Hard. 6.5, 7.0. Sp.gr. 3.27. Transparent, translucent. Lustre vitreous. Colour bluish, greyish, reddish-brown, of several shades. Streak white.

Massive varieties, amorphous, structure lamellar, granular.

Found in Dauphiny, and at Botallack in Cornwall, and in other places.

**AZOTIC GAS, No. 44.**

Is said to be contained in the Bath hot springs, and to rise with the vapour from the public bath.

**AZURITE. Klaprothite. Tyrolite. Voroulite, No. 499.**

Haüy, 3.54. Phil. 94. Haid. 2.290. Leon. 136. Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 121^\circ 30'$ . Cleavage indistinct. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 3.056. Translucent, opaque. Lustre vitreous. Colour blue. Streak white.

Massive varieties, amorphous, structure granular.

Found in Salzburg, and in rolled crystalline masses in Brazil.

**AMPHOHELITE, No. 331.**

A Mineral found in Finland, having the form, cleavage, and colour of Labradorite.

**BARINGTONITE, No. 332.**

Haid. 3.75. Leon. 721.

Occurs in attached crystals.

Primary form a Doubly oblique prism. Cryst. fig. 95.  $P, M = 92^\circ 34'$ .  $P, T = 85^\circ$ .  $M, T = 112^\circ 30'$ . Cleavage parallel to P and T. Fracture uneven. Hard. 5.5, 6.0. Faintly translucent. Lustre vitreous. Colour black, sometimes greenish.

Found at Arendal in Norway, associated with Cleavelandite.

**BARYTES.**

*Carbonate of Barytes.*

**a. WITHERITE. Barolite, No. 438.**

Haüy, 2.25. Phil. 182. Haid. 2.119. Leon. 330. Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 118^\circ 30'$ . Fracture uneven. Hard. 3.0, 3.5. Sp.gr. 4.3. Transparent, translucent. Lustre vitreo-resinous. Colour white, sometimes greyish or yellowish. Streak white.

Massive varieties, globular, botryoidal, reniform. Structure, large, fibrous, sometimes granular.

Found principally in England, in Shropshire, Lancashire, Durham, and Westmoreland, and occasionally in small quantities in Siberia, Hungary, and other places.

*Carbonate of Lime and Barytes.*

**a. BARYTO-CALCITE, No. 443.**

Haid. 3.76. Leon. 327.

Occurs in attached crystals and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 88.  $P, M = 102^\circ 54'$ .  $M, M' = 106^\circ 54'$ .

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Cleavage parallel to P and M, distinct. Fracture uneven. Hard. 4.0. Sp.gr. 3.66. Transparent, translucent. Lustre vitreo-resinous. Colour white, sometimes yellowish or greenish. Streak white.

Massive varieties, amorphous. Structure granular. Found at Alston Moor, Cumberland.

*Sulphate of Barytes.*

**a. BAROSELENITE. Bolognian Spar. Cawk, No. 527.**

Haüy, 2.5. Phil. 183. Haid. 2.121. Leon. 255. Occurs crystallized and massive.

Primary form a Right rhombic prism. Cryst. fig. 72.  $M, M' = 101^\circ 42'$ . Cleavage parallel to P and M. Fracture conchoidal. Hard. 3.0, 3.5. Sp.gr. 4.416, 4.7. Transparent, translucent. Lustre vitreous. Colour white, blue, yellow, brown. Streak white.

Massive varieties, occasionally globular, reniform, amorphous. Structure fibrous, granular, compact. Found in several localities in most Countries, and in different geological positions.

*Sulphate of Barytes and Fluuate of Lime.*

**a. BARYTO-FLUORITE, No. 528.**

An. 16.48.

Occurs in a vein in coarse shell limestone in Derbyshire, and nearly resembles fine compact grey limestone. Hard. 4. Sp.gr. 3.75.

**BERGMANNITE. Spreüstein. Radiolite of Esmark, No. 333.**

Haüy, 4.484. Phil. 200. Haid. 3.77. Leon. 474.

Occurs massive, amorphous. Structure fibrous, sometimes radiating. Hard 7.0, 7.5. Sp.gr. 2.3. Opaque. Colour greyish-white, dull yellow, and red. Lustre pearly.

Found near Stavern in Norway.

**BIOTINE, No. 334.**

The crystals of this substance appear to correspond in form and measurement with those of Anorthite, of which they will probably be found to be a variety.

**BISMUTH.**

*Arseniuret of Bismuth?*

**ARSENICAL BISMUTH, No. 34.**

Haid. 3.74. Leon. 720.

Occurs in aggregations of small globular forms. Structure fibrous or curved lamellar. Fracture uneven. Soft. Heavy. Lustre resinous. Colour dark hair-brown.

Found at Schneeberg in Saxony.

*Carbonate of Bismuth.*

**AGNESITE, No. 456.**

B.M. Tab. 344. Phil. 274. Leon. 787.

Resembles stearite, but more earthy, and harsher to the touch.

Found at St. Agnes, Cornwall.

*Silicious Carbonate of Bismuth.*

**BISMUTH-BLENDE, No. 457.**

E.J.S. 7.342.

Occurs in attached crystals, and in globular and stactitic masses.

Primary form a Cube. Cryst. fig. 56. Cleavage imperfect. Fracture conchoidal. Hard. 4.5, 5.0. Sp.gr. 5.9, 6.0. Translucent, opaque. Lustre bright resinous. Colour reddish and yellowish-brown. Streak yellowish-grey.

Found at Schneeberg in Saxony.

**NATIVE BISMUTH, No. 9.**

Haüy, 4.202. Phil. 272. Haid. 2.43. Leon. 693.



Mineralogy

Occurs crystallized and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to planes of *Mod. a*. Fracture indistinct. Hard. 2.01, 2.5. Sp.gr. 9.737. Opaque. Lustre metallic. Colour of fresh cleavage reddish-silver-white, but tarnishes on exposure to air. Streak unchanged.

*Massive varieties*, amorphous, structure granular. Found in several mines in Saxony, and in most other mining districts of Europe.

*Oxide of Bismuth.*

**a. BISMUTH OCHRE, No. 137.**

Hauy, 4.214. Phil. 274. Leon. 561.

Occurs massive, amorphous, sometimes minutely disseminated. Fracture earthy. Soft. Sp.gr. 4.7.

Opaque, Dull. Colour greenish or greyish-yellow. Found in Saxony and Bohemia.

*Seleniuret of Bismuth and Tellurium.*

**a. BASTNAITE, No. 46. Leon. 589.**

Occurs in small, imbedded, laminated masses. Sp.gr. 7.8. Lustre metallic. Colour between steel and lead-grey.

Found at Bastnaes in Sweden.

*Sulphuret of Bismuth.*

**a. BISMUTH GLANCE, No. 84.**

Hauy, 4.210. Phil. 273. Haid. 3.19. Leon. 616. Occurs in attached and imbedded crystals, and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' \text{ about } 91^\circ$ . Cleavage parallel to *P*, and to the greater diagonal of the prism. Fracture indistinct. Opaque. Lustre metallic. Colour lead to steel-grey. Streak the same.

*Massive varieties*, amorphous, structure granular or fibrous, the fibres promiscuously aggregated.

Found sparingly in Saxony, Bohemia, Hungary, and some other places in Europe, and in England in Cornwall and Cumberland.

*Sulphuret of Bismuth and Copper.*

**a. CUPREOUS BISMUTH, No. 85.**

Phil. 274. Haid. 3.91. Leon. 619.

Occurs massive. Structure small-fibrous. Fracture uneven. Opaque. Lustre metallic. Colour lead-grey to steel-grey.

Found at Fürstenberg, in veins accompanying other ores of bismuth, cobalt, &c.

*Sulphuret of Bismuth, Lead, and Copper.*

**a. NEEDLE ORE, No. 86.**

Phil. 274. Haid. 3.130. Leon. 618.

Occurs in imbedded prismatic crystals, in quartz.

Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 6.125.

Opaque. Lustre metallic. Colour dark lead-grey. Found near Catharinenburg in Siberia.

*Sulpho-telluret of Bismuth.*

**a. BORNITE. Telluret of Bismuth, No. 20.**

Occurs in imbedded, imperfect, rhombic and hexagonal crystals, and small foliated masses.

Primary form a Rhomboid. Cryst. fig. 106. The crystals macle in several directions. Cleavage perpendicular to the axis, very distinct. Sp.gr. 7.5.

\*Lustre highly metallic. Colour bright steel-grey.

Found at Schoubkan, near Schemnitz, Hungary.

**BORACIC ACID. Sassolin, No. 423.**

Hauy, 1.297. Phil. 144. Haid. 2.25. Leon. 146.

Occurs naturally in scaly or granular crystalline aggregations, which are very friable.

Translucent. Lustre pearly. Colour greyish and yellowish-white. Streak white. Taste slightly acid and bitter. Sp.gr. 1.480.

Found at Volcano, one of the Lipari Islands, and in other volcanic districts.

**BOVELITE. Pseudo Sommite, No. 335.**

Phil. 126. Leon. 468.

Occurs in attached hexagonal prisms.

Primary form a Rhomboid. Cryst. fig. 106. Transparent. Lustre vitreous. Colour white. Streak white.

Found at Capo di Bova, near Rome, and has hitherto been distinguished from Nepheline only by its *not gelatinizing in acids* as that Mineral does. Its secondary forms, if observed, have not been described.

**BREISLAKITE, No. 568.**

Haid. 3.80. Leon. 722.

Occurs in capillary brownish fibres, covering and filling cavities in some of the substances ejected from Vesuvius. It is said to contain a considerable portion of copper, but its other constituents are not known.

**BREWSTERITE, No. 216**

Phil. 200. Haid. 3.80. Leon. 193, 723.

Occurs in attached crystals.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M \text{ about } 92^\circ$ ,  $M, M' = 136^\circ$ . Cleavage parallel to the oblique diagonal. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 2.2. Transparent, translucent. Lustre vitreous. Colour yellowish and greyish-white, and occasionally colourless.

Found at Strontian in Scotland.

**BRONZITE. No. 286**

Hauy, 2.455. Phil. 25.71. Haid. 2.207. Leon. 518.

Occurs in massive aggregations of columnar crystals. Cleavage parallel to the lateral plane and both diagonals of a Rhombic prism of  $93^\circ 30'$ . Fracture uneven. Hard. 4.0, 5.0. Sp.gr. 3.25. Translucent. Lustre vitreous, pseudo-metallic on cleavage planes. Colour greenish or greyish-brown. Streak lighter colour.

Found in serpentine in Stiria, in greenstone in the Hartz, and in other places.

**BUCKLANDITE, No. 336.**

An. n.s. 7.134. Haid. 3.83. Leon. 725.

Occurs in attached crystals.

Primary form an Oblique rhombic prism.  $P, M = 103^\circ 56'$ ,  $M, M' = 70^\circ 40'$ . Leay. Opaque. Colour dark brownish-black.

Found near Arendal in Norway, and at Laach on the Rhine.

**BUSTAMITE, No. 274.**

S. 18.392.

Structure bladed. Hard. 6.5. Sp.gr. 3.1, 3.3. Nearly opaque. Colour grey, greenish, and reddish.

Found in Mexico.

**CADMIUM.** A metal found in small quantities accompanying zinc in several of its ores, particularly in the fibrous blende from Przibram in Bohemia.

**CARBON.**

**a. DIAMOND, No. 40.**

Hauy, 4.419. Phil. 361. Haid. 2.306. Leon. 669.

Mineralogy

Occurs in imbedded crystals in alluvial ground.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron, very distinct. Fracture conchoidal. Hard. 10.0. Sp.gr. 3.52. Transparent, but sometimes rendered opaque by foreign matter. Lustre adamantine. Colour white, sometimes grey, blue, green, yellow, red, brown, black. Streak greyish.

Found in the East Indies and in Brazil.

#### 2. COAL.

##### a. Not bituminous. ANTHRACITE, No. 41.

Hauy, 440. Phil. 364. Haid. 3.64. Leon. 672. 803. Occurs massive, amorphous. Structure columnar, compact. Fracture conchoidal. Hard. 2.0, 2.5. Sp.gr. 1.4, 1.5. Opaque. Lustre imperfect metallic. Colour grey to non-black. Streak the same. Found in most Countries.

##### b. Bituminous. No. 586.

Hauy, 4.459, 470. Phil. 370, 371. Haid. 3.61. Leon. This includes the common, the Cannel, and all the varieties of fossil coal.

Occurs massive, amorphous. Structure foliated, granular, compact, earthy, and resembling wood. Fracture conchoidal, uneven. Lustre resinous, of different degrees. Colour black, brown, brownish, and greenish-yellow.

Found in most parts of the World, associated with vegetable organic remains.

##### c. Wood Coal. LIGNITE. No. 574.

Phil. 372.

Occurs massive. Structure fibrous, compact, resembling wood. Fracture of some varieties conchoidal. Opaque. Lustre resinous, dull. Colour brown, of several shades, to black.

Found in several parts of Europe and America.

##### d. Paper Coal. DYSODILE. No. 575.

N.J. 24 223. Phil. 372.

Occurs in amorphous masses. Structure foliated, the leaves thin and a little flexible. Sp.gr. 1.146. Opaque, but becomes translucent after immersion in water. Colour greenish and yellowish-grey. When burned it produces a strong and fetid bituminous odour.

Found in a thin stratum between two beds of secondary limestone at Melilli, near Syracuse in Sicily.

##### e. BITUMEN.

Hauy, 4.452. Phil. 366 to 369. Haid. 3.59. Leon. 797, 799, 801.

##### a. Liquid. NAPHTHA. No. 580.

Transparent. Colourless, or slightly tinged with yellow. Odour peculiar, termed bituminous. Found chiefly on the coast of the Caspian Sea.

##### b. Viscid. PETROLEUM, No. 561.

Slightly translucent. Colour dark reddish-brown. Odour bituminous.

Found in many parts of Europe and America, but chiefly in Asia, flowing from beds associated with coal strata. As much as 400,000 hogsheads is said to be collected annually in the Birman Empire. It is also abundant in Persia.

##### c. Elastic. ELATERITE, No. 582.

Soft, flexible. Opaque. Colour brown, sometimes greenish. Odour bituminous. Found only in the Odin mine, near Castleton, Derbyshire.

##### d. Earthy. MALTHA.

Less free from extraneous matter than the preceding

varieties, to which circumstance it probably owes its earthy character.

Fracture uneven. Soft. Opaque. Colour blackish-brown. Odour bituminous.

Found chiefly in Persia, and less frequently in other places than the other varieties.

##### e. Earthy, containing Benzoic Acid. MURINDO.

Q.J. N.S. 3.387.

Occurs massive. Fracture earthy. Yields to the nail. Floats in water. Opaque. Dull. Colour externally blackish-brown, internally lighter. Tastes hot and peculiar. Smell pungent.

Found at Murindo, Province of Choco, Columbia.

##### f. Compact. ASPHALTUM. Jew's Pitch, No. 585.

Fracture conchoidal. Hard. 2. Sp.gr. 1.16. Opaque. Lustre vitreous, resinous. Colour brown to black. Found in Albania, on the shores of the Dead Sea, in considerable quantities; in the Islands of Barbadoes and Trinidad, and occasionally in other places.

It is supposed to have been used by the Egyptians in embalming the bodies of the dead, and has been employed in the West Indies instead of pitch for calking the bottoms of ships.

These varieties of bitumen pass by insensible degrees from the transparent fluid to the opaque solid, and hence they are regarded as appertaining to the same Mineral species.

##### d. RETINASPHALTUM, No. 577.

Phil. 375. Haid. 3.146. Leon. 793.

Occurs in amorphous lumps of different sizes, imbedded in wood coal. Fracture imperfect, conchoidal. Hard. 1.5, 2.0. Sp.gr. 1.135. Opaque. Lustre resinous. Colour pale brownish-yellow.

Found at Bovey Tracey, Devonshire, and is also said to have been found at Halle and some other places on the Continent, accompanying earthy brown coal, and of different colours.

##### e. Fossil COPAL. Highgate Resin, No. 578.

Phil. 375.

Found in blue clay at Highgate near London, and at Wolchow in Moravia, in small nodular masses. Fracture conchoidal. Sp.gr. 1.046. Nearly opaque. Lustre resinous. Colour dull brown.

##### f. AMBER, No. 576.

Phil. 373. Haid. 3.57. Leon. 791.

Occurs in nodular masses, sometimes very small. Fracture conchoidal. Hard. 2.0, 2.5. Sp.gr. 1.08. Transparent to opaque. Lustre resinous. Colour yellowish-white, brown, red, yellow. Streak white.

Found on the coasts in the Baltic, and in beds of wood coal in several places in Europe and other Countries.

##### g. HATCHERINE. Mineral Adipocire, No. 579.

An. 1.136. Phil. 374. Haid. 3.106. Leon. 795.

Occurs in thin flakes and in granular masses in cavities of lime or ironstone. Very soft and light. The flakes translucent, with a slightly glistening and pearly lustre, the granular masses opaque and dull. Colour yellowish-white, and wax and greenish-yellow, without odour and not elastic. Combustible.

Found at Merthyr Tydvil in South Wales.

##### h. NATIVE NAPHTHALINE, No. 587.

Q.J. 4.446.

Occurs crystalline, cleavable in some directions, with

Mineralogy

## Mineralogy

a conchoidal fracture in others. Sp.gr. 1.0, 1.5. Transparent. Lustre adamantine. Colour white, yellow, green. Has the appearance of Talc.

Found in the fissures of bituminous wood in the coal formation of Urnach, Canton of St. Gall.

## j. SCHERERITE, No. 588.

Q.J. 5.431.

Occurs between the fibres of fossil wood in acicular crystals, and small layers. Translucent. Lustre nacreous. Colour white or yellowish white.

Found at Urnach, Canton of St. Gall, Switzerland, in a coal formation.

## CAVOLINITE, No. 337.

The crystalline forms of this Mineral correspond very nearly with those of Nepheline and Davyne; but its lustre is highly pearly instead of vitreous, and it may be cleaved with much greater facility. It is found at Mount Vesuvius.

## CEREOLITE, No. 338.

The Marquis de Dree first gave this name to a soft yellowish waxy looking substance occurring in a greyish matrix, in small irregular nodules. Several other soft Minerals, differing in many of their characters from that of De Dree, have since passed under the same name, but there do not appear to be any published descriptions or analyses of them.

De Dree's Mineral was found near Lisbon.

## CERIUM.

## a. CARBONATE OF CERIUM, No. 455

E.J.S. 3.334. Leon. 726.

Occurs in white crystalline coatings on the Cerite of Bastnaes, in Sweden.

## b. FLUATE OF CERIUM, No. 509.

Phil. 266. Haid. 3.100. Leon. 571.

Is said to occur in six-sided prisms, plates, and amorphous masses. Colour reddish. No other characters given.

Found very sparingly at Finbo, Broddbo, and Bastnaes, near Fahlun, in Sweden.

## c. SUB-FLUATE OF CERIUM, No. 510.

Phil. 266. Haid. 3.101. Leon. 243.

Resembles porcelain jasper, but with traces of crystallization. Colour yellow.

Found at Finbo in Sweden.

## d. FLUATE OF CERIUM AND YTTRIA, No. 511.

Phil. 267. Haid. 3.101

Occurs in small imbedded masses, and sometimes thinly investing Gadolinite. Earthy. Soft. Colour red, of different shades, yellow, white.

Said, by Berzelius, to be a mechanical mixture of the fluates of yttria and of cerium with silica.

## e. YTTRIO-CERITE, Fluates of Cerium, Yttria, and Lime, No. 512.

Phil. 265. Haid. 3.172. Leon. 573.

Occurs massive, structure granular, compact. Fracture uneven. Hard. 6.5. Sp.gr. 3.447. Opaque. Colour violet-blue, greyish-red, and greyish-white.

Found at Finbo and Broddbo in Sweden.

## f. SILICATE OF CERIUM, No. 171.

E.J.S. 6.357. Leon. 227.

Occurs in small imbedded nodules and hexagonal prisms, in magnesian carbonate of lime. Cleavage parallel to the lateral planes. Fracture uneven. Translucent. Colour pale yellowish-brown.

Found at Santa Fé de Bogota, accompanying the precious Emeralds from that locality.

*Silicate of Cerium and Iron.*

## a. CERITE, No. 170.

Haid. 4.393. Phil. 263. Haid. 2.394. Leon. 227.

Occurs in amorphous imbedded masses. Structure fine granular. Fracture uneven. Hard. 5.5. Sp.gr. 4.912. Slightly translucent. Lustre resinous. Colour pale dull red, sometimes greyish. Streak white.

Found near Riddarhittan in Sweden, imbedded in or accompanying Cerine.

## b. CERINE, No. 319.

Haid. 4.395. Phil. 265. Haid. 2.395. Leon. 481.

Occurs massive, and rarely in attached imperfect crystals. Hard. 5.5, 6.0. Sp.gr. 4.173. Opaque. Lustre imperfect metallic. Colour brownish-black. Streak brownish-grey.

Found near Riddarhittan in Sweden.

## c. ALLANITE, No. 320.

Haid. 3.68. Leon. 481.

Occurs crystallized and massive.

Primary form is said by Phillips to be a Square prism, and by Haidinger, a Doubly oblique prism, whence it appears that two different Minerals have been described under the same name. Fracture, according to Haidinger, imperfect conchoidal. Hard 6.0. Sp.gr. 4.0. Opaque. Lustre imperfect metallic. Colour brownish-black. Streak greenish-grey.

Found at Alluk, East Greenland.

The Allanite of Phillips is probably the Fergusonite of Haidinger.

*Silicate of Cerium, Iron, Alumina, and Lime.*

## a. ORTHITE, No. 327.

Phil. 265. Haid. 3.133. Leon. 210.

Occurs in small, slender, columnar, imbedded masses. Fracture conchoidal. Hard. 6.0, 7.0. Sp.gr. 3.255. Opaque. Lustre vitreous. Colour brownish-black. Streak brownish-grey.

Found at Finbo in Sweden, in a granitic vein, traversing gneiss, and, in larger imbedded masses, in Finland.

## b. PYRORHITE, containing Carbon, No. 328.

Phil. 265. Haid. 3.142. Leon. 773.

Occurs in single or aggregated, slender, columnar masses, imbedded in granite or quartz. Fracture conchoidal, uneven, earthy. Hard. 2.5. Sp.gr. 2.19. Opaque. Lustre resinous. Colour brownish-black. the same.

Found near Fahlun in Sweden.

## CHABASIE, No. 205

Haid. 3.163. Phil. 138. Haid. 2.232. Leon. 198.

Occurs in attached crystals.

Primary form a Rhomboid. Cryst. fig. 106. P.P' = 94° 46'. Cleavage parallel to P, nearly distinct. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 2.1. Transparent, translucent. Lustre vitreous. Colour white, sometimes reddish or yellowish. Streak white.

Found in the Faro Islands, in Iceland, in many parts of Europe, and in America.

## CHIASTOLITE. Crucite. Macle, No. 186.

Haid. 2.365. Phil. 201. Haid. 3.84. Leon. 726.

Occurs in imbedded crystals in clay-slate.

Primary form unknown. The crystals are nearly

Mineralogy

Square prisms, composed of a greyish or reddish substance, enclosing a central black prism, and occasionally four others within its lateral edges, connected with the central one by four black thin plates. Cleavage parallel to the lateral planes. Fracture splintery. Hard. 5.0, 5.5. Sp.gr. 2.944. Translucent, opaque. Lustre vitreo-resinous. Colour greyish and yellowish, or reddish-white. Streak white.

Found in many parts of Europe and America.

• **CHILDRENITE**, No. 502.  
Q.J.S. 16,274. Haid. 3.85. Leon. 137. 728.  
Occurs in minute attached crystals.  
Primary form a Right rhombic prism.  $M, M' = 92^\circ 48'$ . Fracture uneven. Hard. 4.5, 5.0. Transparent, translucent. Lustre vitreous. Colour yellow. Streak white.  
Found in the neighbourhood of Tavistock in Devonshire, and at Crinnis in Cornwall.

**CHLOROPHAEITE**, No. 173.  
Macculloch, Western Isles, 1.504. Phil. 202. Haid. 3.86. Leon. 729.  
Occurs in small masses imbedded in basalt. Fracture conchoidal. May be scratched by a quill. Sp.gr. 2.02. Transparent, opaque. Lustre vitreous. Colour green when first broken, but afterwards becomes black.  
Found in the Isle of Rum, in Fifeshire, and in Iceland.

**OXIDE OF CHROME**, No. 419.  
Phil. 271. Leon. 557.  
Occurs in compact or pulverulent masses, coating or filling cavities in the chromate of iron at Unst, one of the Shetland Isles. Structure of the compact approaches to crystalline. Translucent. Lustre resinous. Colour grass-green and pale-yellow.  
It is also found colouring granular quartz at Ecouchetz in Burgundy.

**CHRYSOBERYL**. *Cymophane*, No. 324.  
Haüy, 2.303. Phil. 89. Haid. 2.304. Leon. 539.  
Occurs in loose crystals in alluvial deposits in Brazil, and in imbedded crystals at Haddam and Saratoga, North America.  
• Primary form a Right rhombic prism.  $M, M' = 120^\circ$ . Cleavage parallel to P, and to the short diagonal of the prism. Fracture conchoidal. Hard. 8.5. Sp.gr. 3.754. Transparent, translucent. Lustre vitreous. Colour yellowish and brownish-green.  
• Frequently with a bluish opalescence. Streak white.  
Found in Brazil and North America.

**CHUSITE**, No. 339.  
Phil. 202. Leon. 533.  
A Mineral found by Saussure in the porphyritic rocks near Lignbourg, and imperfectly described as occurring massive or granular. Translucent. Lustre greasy.

**CLEAVELANDITE**. *Albite*. *Silicious Spar*, No. 227.  
Haüy, 3.70. Phil. 113. Haid. 2.255. Leon. 417.  
Occurs in attached crystals and massive.  
Primary form a Doubly oblique prism.  $P, M = 93^\circ 30'$ .  $P, T = 115^\circ$ .  $M, T = 119^\circ 30'$ . Cleavage parallel to the primary planes. Fracture uneven. Hard. 6.0. Sp.gr. 2.61, 2.68. Transparent, translucent. Lustre vitreous. Colour white, grey, pale blue, greenish, red. Streak generally white.  
Massive varieties amorphous. Structure lamellar.  
Found in Dauphiny, at St. Gothard, and generally

accompanying felspar in most of its numerous localities.

Mineralogy

COBALT.

*Arseniate of Cobalt.*

a. **RED COBALT**. *Cobalt bloom*, No. 472.  
Haüy, 4.232. Phil. 281. Haid. 2.184. Leon. 162.  
Occurs sometimes in attached thin crystals, but generally as fine fibres, forming small globular tufts, or evenly coating the matrix, and also pulverulent and massive.  
Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 101^\circ 13'$ .  $M, M' = 55^\circ 15'$ . Cleavage parallel to a plane passing through the oblique diagonal, very distinct. Hard. 1.5, 2.0. Sp.gr. 2.948. Transparent, translucent. Lustre vitreous. Colour red, of various shades, sometimes pearl or greenish-grey. Streak lighter colour. Splits easily into thin laminæ, which are very flexible.  
Massive variety amorphous; structure fibrous, often radiating.  
• Found principally in Saxony and Bohemia.

b. **ROSELITE?** No. 473.  
An. n.s. 8 439.  
Occurs in attached crystals on greyish quartz.  
Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 125^\circ 7'$ . Cleavage parallel to P. Fracture conchoidal. Hard. 3.0. Translucent. Lustre vitreous. Colour deep rose-red.  
Found at Schneeberg in Saxony.

*Arseniuret of Cobalt?*

a. **WHITE COBALT**, No. 29.  
Haüy, 4 219. Phil. 278. Haid. 2.152. Leon. 654. 680.  
Occurs in imbedded crystals, generally single, and massive.  
Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the primary planes, very distinct. Fracture uneven. Hard. 5.5. Sp.gr. 6.3. Lustre metallic. Colour silver-white. Streak greyish-black.  
Massive variety amorphous; structure granular.  
Found in Norway; in fine crystals at Tunaberg in Sweden; in Silesia, and in Cornwall.

b. **HARD WHITE COBALT**, No. 30.  
E.N.P.J. 3.271.  
Occurs crystallized. Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the cube distinct; less so parallel to *Mod. a*, and still less parallel to *Mod. c*. Sp.gr. 6.74, 6.84. Distinguished from white cobalt by its more distinct cleavage and greater sp.gr.  
Found at Skutterud in Norway.

c. **RADIATED WHITE COBALT**, No. 31.  
Haid. 2.454. Leon. 162?  
Is said to crystallize in Rhombic prisms, but no distinct characters of it have been given.  
Found at Schneeberg in Saxony.

d. **RHOMBIC WHITE COBALT**, No. 32.  
Found at Håkhambo in Sweden, having the bright lustre of arsenical cobalt, and the form and measurements of arsenical iron. No analysis or description has been given.

*Sulpho-arseniuret of Cobalt and Iron.*

a. **GREY COBALT**, No. 43.  
Haüy, 4.225. Phil. 278. Haid. 2.455. Leon. 6.80.

Mineralogy

Occurs in attached crystals and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the plane of the Cube, Octahedron, and Rhombic dodecahedron, indistinct. Fracture uneven. Hard. 5.5. Sp.gr. 6.466. Lustre metallic. Colour greyish-tin-white. Streak greyish-black.

Massive varieties, reticulated; amorphous. Structure granular, compact.

Found principally at Schneeberg in Saxony, and in Bohemia. Used in the manufacture of Smalt.

b. Grey cobalt? No. 114.

Brit.Min. tab. 472.

Is described as amorphous. Fracture uneven, like broken steel, and very brittle. Sp.gr. 5.5, 7.2. Lustre metallic. Colour rather dull steel-grey. Streak brighter.

Found at Dolcoath mine in Cornwall.

The white and grey ores of cobalt require a more precise examination than they have hitherto received, which will probably separate them into distinct species.

*Cobalto-bismuthic Arsenic.*

a. KERSTENITE, No. 33.

E.J.S. 6.355. Leon. 720?

Massive. Structure fibrous, imperfect radiated, rather porous. Sp.gr. 6.0, 6.7. Lustre nearly metallic. Colour between lead-grey and steel-grey.

Found at Schneeberg in Saxony.

*Oxide of Cobalt and Manganese.*

a. EARTHY COBALT. Cobalt ochre, No. 129.

Haüy, 4.230. Phil. 251. Haid. 378. Leon. 162.3, 238.9.

Occurs in botryoidal, stalactitic, and amorphous masses. Structure fine granular, earthy. Soft. Sp.gr. 2.2. Opaque. Colour bluish-black, brownish, and yellowish. Streak shining.

Found in Hessia, Thuringia, and other depositaries of the ores of cobalt.

It is not improbable that the brown and yellow varieties may upon further examination appear not to belong to one species.

*Sulphate of Cobalt.*

a. SULPHATE OF COBALT, No. 547.

Phil. 282. Haid. 3145. Leon. 114.

Occurs in small globular, stalactitic, and amorphous masses, thinly investing other Minerals. Soft. Soluble in water. Translucent. Lustre vitreous, often dull externally. Colour pale rose-red.

Found among the mining heaps of old mines at Bieber, near Hanau, and in Sulzburg.

*Sulphuret of Cobalt.*

a. SULPHURET OF COBALT, No. 75.

Phil. 280. Haid. 388. Leon. 653.

Occurs in imbedded amorphous masses. Structure fine granular, compact. Fracture uneven. Lustre metallic. Colour steel-grey, with a reddish tarnish. Streak grey.

Found at Riddarhittan in Sweden.

COMPTONITE, No. 340.

Phil. 201. Haid. 389. Leon. 193. 730.

Occurs in attached crystals in the cavities of fragments of an amygdaloidal rock at Vesuvius.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 91^\circ$ . Cleavage parallel to both diagonals of the terminal planes. Fracture uneven. Hard.

5.0, 5.5. Transparent, translucent. Lustre vitreous. Colour white. Streak white.

Found at Vesuvius, and in a trap rock in Bohemia.

CONDRODITE. *Brucite*. *Macchireite*, No. 515.

Haüy, 2.476. Phil. 97. Haid. 387. Leon. 533.

Occurs in imbedded, rounded nodules of various sizes, generally small, the larger ones sometimes protruding into cavities in the matrix, and presenting crystalline forms not yet described.

Cleavage described as parallel to the lateral planes of a Rhombic prism of  $124^\circ$ . Fracture uneven. Hard 6.5. Sp.gr. 3.2, 3.5. Transparent, translucent. Lustre vitreous. Colour yellow to brown.

Found in Finland, and in several parts of North America. And it is probable, from the difference in appearance of different specimens, that the name has been given to two or more different substances.

## COPPER.

*Arsenate of Copper.*

*Right prismatic.*

a. LINSNERZ. *Octahedral Arsenate*, No. 477.

Haüy, 3.509. Phil. 316. Haid. 2.160. Leon. 172.

Occurs in attached, obtuse, octahedral crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.

$M, M' = 107^\circ 5'$ . Levy. Cleavage parallel to the primary planes. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 2.926. Transparent, translucent. Lustre vitreous. Colour light blue and occasionally dull green. Streak pale blue or green.

Found in Cornwall near Redruth, and in Hungary.

b. OLIVENITE. *Olivenerz*, No. 478.

Haüy, 3.510. Phil. 319. Haid. 2.164. Leon. 168.

Occurs crystallized and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.

$M, M' = 110^\circ 30'$ . Levy. Cleavage parallel to the primary planes. Fracture uneven. Hard. 3.0. Sp.gr. 4.28. Transparent, translucent. Lustre vitreous, bright. Colour various shades of green, generally inclining to olive. Streak paler green.

Massive varieties, globular, reniform, nodular. Structure fibrous, occasionally granular, compact.

Found in Cornwall near Redruth, and near Alston-moor in Cumberland.

c. EUCHROITE, No. 479.

Haid. 3.94. Leon. 173.

Occurs in attached or imbedded crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.

$M, M' = 117^\circ 20'$ . Cleavage parallel to M indistinct. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 3.39. Transparent, translucent. Lustre vitreous. Colour emerald-green. Streak lighter green.

Found at Libethen in Hungary.

*Oblique prismatic.*

a. TRIEDRAL *Arsenate* of Bournon, No. 480.

Phil. 318. Haid. 3.144. Leon. 170.

Occurs crystallized and massive.

Primary form an Oblique rhombic prism. Cryst. fig.

83.  $P, M = 95^\circ$ .  $M, M' = 56^\circ$ . Cleavage parallel to P. Fracture indistinct. Hard. 2.5, 3.0. Sp.gr. 4.2. Transparent, translucent. Lustre vitreous. Colour dark blue to blackish-green. Streak paler green.

Massive varieties, reniform, amorphous, with a lamellar structure.

Found in Cornwall near Redruth.

*Rhombohedral.*

a. COPPER NICA, No. 491.

Mineralogy

Mineralogy

Häuy, 3.509. Phil. 317. Haid. 2.178. Leon. 171. Occurs in attached crystals.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 69^\circ 48'$ . Levy. Crystals usually tabular, thin. Occasionally in floriform groups. Cleavage distinct, perpendicular to the axis, less so parallel to P. Fracture uneven. Hard. 2.0. Sp.gr. 2.549. Transparent, translucent. Lustre vitreous. Colour emerald-green. Streak rather pale green.

Found in Cornwall near Redruth.

Not Crystallized.

a. ERINITE, No. 482.

E.J.S. 9.93.

Occurs in concentric layers, between which other arseniates are found. No crystals observable. The surface of the layers rough, the fracture uneven, with slightly resinous lustre. Hard. 4.5, 5.0. Sp.gr. 4.04. Slightly translucent. Colour emerald-green. Streak paler green.

Found near Limerick.

b. CONDURRITE, No. 483.

P.M. and An. 2.286.

Considered by Mr. Phillips to be an accidental deposit resulting from the decomposition of other ores containing copper and arsenic.

Amorphous. Fracture conchoidal. Scratched by glass. When cut by a knife a polished lead-grey surface is produced. Sp.gr. 5.20. Opaque. Surface of fracture very smooth. Colour brownish-black. Streak black.

Found in Condurrow Mine, near Camborne, Cornwall.

*Arseniuret of Copper?* No. 35.

P.M. and An. 2.287.

Metallic. Amorphous. Yields to the knife. Malleable. Colour tin-white.

Found in Condurrow mine, near Camborne, Cornwall, accompanying and coated by Condurrite.

*Carbonate of Copper.*

a. BLUE CARBONATE OF COPPER, No. 461.

Häuy, 4.3. Phil. 309. Haid. 2.167. Leon. 152.

Occurs crystallized and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 91^\circ 30'$ ,  $M, M' = 98^\circ 50'$ . Cleavage parallel to P, dull, and also to M, and both diagonals, and to c. Cryst. fig. 83. Fracture uneven. Structure fibrous, large or small, parallel or diverging, sometimes curved, and lamellar transversely to the direction of the fibres. Occasionally granular, sometimes earthy. Hard. 3.5, 4.0. Sp.gr. 3.83. Transparent, translucent. Lustre vitreous, bright. Colour various shades of blue. Streak paler blue.

Massive varieties, globular, botryoidal, reniform, stalactitic.

Found in fine crystals at Chessy, near Lyons in France, in Siberia, the Bannat, Cornwall, and many other places.

b. MALACHITE, Green Carbonate of Copper, No. 460.

Häuy, 3.489. Phil. 310. Haid. 2.175. Leon. 155. Occurs crystallized and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 112^\circ 33'$ ,  $M, M' = 107^\circ 16'$ . The crystals generally acicular, and too slender for measurement. Cleavage parallel to P and to the oblique diagonal of the terminal planes. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 4.0. Transparent, translucent. Lustre vitreous, bright. Colour various shades of green. Streak paler green.

Massive varieties, amorphous, or in tuberos, globular reniform, botryoidal, and stalactitic shapes. Structure fibrous, the fibres sometimes so slender as to appear compact, and then producing a silky lustre, and yielding a conchoidal fracture.

Found in the same places, generally, as the blue carbonate.

Crystals of green carbonate sometimes occur under the forms of blue carbonate and of red oxide, from which they have been produced by some natural process in the mine. These are termed Epigene by Häuy.

c. ANHYDROUS CARBONATE OF COPPER, No. 463.

Phil. Tr. 1814, p. 45. An. 16. 39.

Occurs amorphous. Structure imperfectly foliated. Fracture small-conchoidal. Easily scratched with a knife. Sp.gr. 2.62. Colour dark blackish-brown. Streak reddish-brown.

Found in India, N.W. of Madras, accompanying Malachite.

*Carbonate of Copper and Zinc.*

a. KUPFERSCHAUM, No. 464.

Haid. 2.180. Leon. 756.

We believe that two or more different Minerals, presenting nearly the same external characters, have been included by different authors under this name. The Mineral here alluded to consists of small, silky tufts or globules, composed of very thin radiating leaves or leafy fibres, without any appearance of crystalline form, or any observable cleavage or fracture. Colour bright bluish-green.

Found in the Bannat, and at Matlock in Derbyshire. Other localities are mentioned, but they possibly relate to some other Mineral.

*Chloride of Copper.*

a. ATACAMITE, Murate of Copper, No. 66.

Häuy, 3.484. Phil. 313. Haid. 3.74. Leon. 212.

Occurs in attached crystals; as a green sand at Atacama in Peru; and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 100^\circ$ . Cleavage parallel to P distinct, less so parallel to M. Fracture uneven. Hard. 3.0, 3.5. Sp.gr. 4.4. Translucent to opaque. Lustre vitreous. Colour green, of various shades, but chiefly dark emerald-green. Streak lighter green.

Massive variety, reniform, with a fibrous structure.

Found principally at Remolinos in Chile.

*Native Copper.*

a. NATIVE COPPER, No. 8.

Häuy, 3.423. Phil. 296. Haid. 2.444. Leon. 710.

Occurs in variously branched and aggregated crystals, in plates and massive. Primary form a Cube. Cryst. fig. 56. No cleavage. Fracture hackly. Hard. 2.5, 3.0. Sp.gr. 7.7, 8.5. Lustre metallic. Colour red, frequently much tarnished. Streak shining.

Massive varieties, generally amorphous.

Found in Cornwall and in most other Countries, in veins, and occasionally in beds.

*Oxide of Copper.*

a. RED OXIDE OF COPPER, Oxydulous Copper. When earthy, Tile-ore, No. 131.

Häuy, 3.462. Phil. 306. Haid. 2.381. Leon. 566.9.

Occurs in attached crystals, and massive, occasionally in thin plates and fibrous.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron.

Mineralogy

## Mineralogy

Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 6.0. Transparent, translucent. Lustre adamantine, approaching sometimes to metallic. Colour red of several shades. Streak dull red.

*Massive varieties*, amorphous. Structure crystalline and amorphous, or botryoidal, with an earthy structure. Found in most copper mines accompanying other ones of this metal.

*Phosphate of Copper.**Right prismatic.*

## a. LIBETHENITE, No. 495.

Haid., 3.519. Phil. 314. Haid. 2.166. Leon. 143. Occurs in small attached octahedral crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 109^\circ 30'$ . Cleavage parallel to P, distinct; less so parallel to M. Fracture uneven. Hard. 4.0. Sp.gr. 3.6. Transparent, translucent. Lustre resinous. Colour dark green. Streak green.

Found principally at Libethen in Hungary.

*Hydrous Phosphate of Copper.*

## a. RHENITE, No. 496.

Haid., 3.519. Phil. 315. Haid. 2.173. Leon. 143. Occurs in attached crystals and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 97^\circ 30'$ .  $M, M' = 37^\circ 30'$ . Cleavage indistinct, parallel to the horizontal diagonal. Fracture uneven. Hard. 4.5, 5.0. Sp.gr. 4.2. Translucent, opaque. Lustre vitreous. Colour various shades of green, frequently blackish. Streak pale green.

*Massive varieties*, botryoidal and amorphous. Structure fibrous.

Found near Rheinbreitbach on the Rhine.

*Seleniuret of Copper.*

## a. SELENIURET OF COPPER, No. 53.

Haid., 3.469. Phil. 304. Haid. 3.150. Leon. 394. Occurs massive and in thin plates in carbonate of lime at Smaland, Sweden. Soft. Malleable. Lustre metallic. Colour silver-white. Streak shining.

*Silicate of Copper.*

## a. DIOPHASE, Emerald Copper, No. 178.

Haid., 3.477. Phil. 312. Haid. 2.171. Leon. 220. Occurs in attached crystals.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 126^\circ 17'$ . Cleavage parallel to P. Fracture uneven. Hard. 5.0. Sp.gr. 3.278. Transparent, translucent. Lustre vitreous. Colour emerald to blackish-green. Streak green.

Found in the Kirghese Steppes, and according to Phillips, at Rishanya in the Bannat.

## b. CHRYSOCOLLA, Copper-green, No. 179.

Haid., 3.471. Phil. 312. Haid. 2.158. Leon. 219. Occurs massive.

No proper crystalline form or cleavage yet observed, but occurring in Siberia and Cornwall in epigene or pseudomorphous crystals, of some of the forms of arseniate, blue carbonate, and red oxide of copper. Hard. 2.0, 3.0. Sp.gr. 2.031. Translucent. Lustre vitreo-resinous. Colour bluish and blackish-green. Streak green.

Several localities are named of this substance, but it is probable that they relate to very different Minerals, some of which appear to be only quartz or calcedony, coloured by carbonate of copper.

*Sulphate of Copper.*

## a. Soluble, No. 534.

Haid., 3.523. Phil. 313. Haid. 2.44. Leon. 411.

## Mineralogy

Occurs in stalactitic, fibrous, and earthy masses. seldom in crystals.

Primary form an Oblique rhombic prism. Cryst. fig. 95.  $P, M = 109^\circ 32'$ .  $P, T = 128^\circ 27'$ .  $M, T = 149^\circ 2'$ . Cleavage indistinct, parallel to T and M. Fracture conchoidal. Hard. 2.5. Sp.gr. 2.213. Transparent, translucent. Lustre vitreous. Colour bright blue. Streak white.

Found in several copper mines in this and other Countries.

## b. BROCHANTITE? No. 545.

Ann. N.S. 8.241. Haid. 3.81. Leon. 724.

Occurs in minute, thin, rectangular crystals. Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 114^\circ 20'$ . Cleavage and fracture uncertain. Hard 3.5, 4.0. Transparent. Lustre vitreous. Colour emerald-green and blackish-green. Found at Cathemenburg in Siberia, covering mammelated green carbonate of copper.

## c. KONIGINE? No. 546.

Ann. N.S. 11. 194.

Primary form a Right rhombic prism, Cryst. fig. 71.  $M, M' = 105^\circ$ . Cleavage perpendicular to axis of prism. Hard. 3.5, 4.0. Translucent. Lustre vitreous. Colour emerald-green and blackish-green. Found at Cathemenburg in Siberia.

*Sulphuret of Copper.*

## a. VITREOUS COPPER, No. 77.

Haid., 3.454. Phil. 297. Haid. 3.8. Leon. 566, 640.

Occurs in attached hexagonal prisms and massive. Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 71^\circ 30'$  nearly. Cleavage parallel to the hexagonal pyramids corresponding to the primary plane. Fracture conchoidal. Hard 2.5, 3.0. Sp.gr. 5.7. Lustre metallic. Colour lead-grey, frequently tarnished. Streak shining.

*Massive varieties*, amorphous; structure granular to compact.

Found in Cornwall, finely crystallized, and in most other depositories of copper ore.

*Sulphuret of Copper, Iron, &c.*

## a. FAHLORE, Grey Copper, No. 78.

## a. Arsenical.

Haid., 3.441. Phil. 300. Haid. 3.1. Leon. 648.

Occurs in attached and imbedded crystals, and massive.

Primary form a Cube. Cryst. fig. 56. Predominating form the regular tetrahedron. Cleavage parallel to the planes of the tetrahedron, very indistinct. Fracture conchoidal. Hard. 3.0, 4.0. Sp.gr. 4.8, 5.1. Opaque. Lustre metallic. Colour steel-grey. Streak nearly the same.

*Massive varieties*, amorphous; structure granular to compact, and sometimes earthy.

Is found accompanying most other copper ores.

## b. Antimonial.

Differs from the arsenical chiefly in colour, which is much darker. It is also more frequently tarnished on the surface, presenting a remarkable contrast to the relative characters of antimony and arsenic in their native state. The fractured surfaces of antimony retaining their metallic brightness after exposure to the air, while those of arsenic speedily become dull and black.

## b. TENNANTITE, No. 79.

Phil. 304. Haid. 3.161. Leon. 604.

Occurs in attached crystals.

Primary form a Cube. Cryst. fig. 56. Cleav



Mineralogy

parallel to the planes of the regular octahedron. Fracture uneven. Hard. exceeding 3.0. Sp.gr. 4.375. Lustre metallic. Colour lead-grey, frequently tarnished on the surface. Streak reddish-grey.

Found in several of the copper mines in Cornwall.

**b. PURPLE COPPER.** *Buntkupfererz*, No. 80.

Haid., 3.436. Phil. 299. Haid. 2.467. Leon. 643. Occurs in attached crystals and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron, indistinct. Fracture uneven. Hard. 3.0. Sp.gr. 5.0. Lustre metallic. Colour purplish and reddish-brown, generally tarnished on the surface. Streak greyish-black.

*Massive variety*, amorphous. Structure compact.

Found in most copper mines.

A variety of this substance occurs in Cornwall, in the form of thin hexagonal prisms, which are probably pseudomorphous

*Sulphuret of Copper and Iron.*

**a. COPPER PYRITES.** *Yellow Copper*, No. 81.

Haid., 3.432. Phil. 302. Haid. 2.469. Leon. 644.

Occurs in attached and imbedded crystals, and massive.

Primary form a Square prism. Cryst. fig. 63.

$P_c = 117^\circ 15'$ . Cleavage parallel to  $c$ , fig. 68. Fracture conchoidal. Hard. 3.5, 4.0. Sp.gr. 4.17, 4.3. Lustre metallic. Colour brass-yellow, frequently with a violet and purple tarnish on the surface. Streak greenish-black.

*Massive varieties*, globular, botryoidal, reniform, stalactitic, and amorphous.

Found in most mines where copper is produced.

**b. KUPFERERZ.** No. 83

Haid. 3.118. Leon. 755.

Occurs in imbedded spheroidal masses, and in flat layers, having an uneven fracture, and a fine granular or earthy structure. Soft. Sp.gr. 3.8. Opaque. Lustre dull resinous. Colour dark blue. Streak shining.

Found in Salzburg and in Thuringia

*Silicate and Sulphate of Copper.*

**a. VELVET COPPER,** No. 567.

Haid. 3.168.

Occurs in very short capillary crystals coating the surface of the matrix, and presenting a velvety appearance. Translucent. Lustre pearly. Colour bright blue.

Found at Moldava in the Bannat, and consists of silica, sulphuric acid, and oxides of copper and zinc.

*Composition unknown.*

**a. PELOKONITE,** No. 569.

E.N.P.J. 12.134.

Occurs amorphous. No cleavage. Fracture conchoidal. Hard. 3.0. Sp.gr. 2.51, 2.57. Opaque. Lustre vitreous, nearly dull. Colour bluish-black. Streak liver-brown.

Found in the Tierra Amarilla and Remolinos in Chili, accompanying green carbonate of copper. Soluble in muriatic acid, the solution yellowish-green. Not analyzed.

**CRYOLITE,** No. 514.

Haid., 2.157. Phil. 197. Haid. 2.66. Leon. 570.

Occurs in single or aggregated crystalline masses.

Primary form not observed. Cleavage parallel to the

terminal and lateral planes of a rectangular prism. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 2.963. Translucent, and becomes more transparent after immersion in water. Lustre vitreous, rather pearly on one surface. Colour white, or reddish, or yellowish-brown. Streak white.

Found at Arksut-fjord, West Greenland.

**DAVYNE,** No. 341.

E.J.S. 7.326. Leon. 433.

Occurs in attached regular hexagonal, prismatic crystals with the terminal edges truncated.

Primary form a Rhomboid. Cryst. fig. 106.  $P.P' = 112^\circ 16'$ . Corresponding nearly, if not exactly, with Nepheline. Cleavage parallel to the planes of the hexagonal prism, distinct. Fracture conchoidal. Hard. 5.0, 5.5. Sp.gr. 2.4. Transparent. Lustre vitreous, pearly upon the cleavage planes. Colour white, sometimes yellowish-brown. Streak white.

Found in cavities, in some of the masses ejected from Vesuvius.

**DESMINE,** No. 342.

Occurs in small silky tufts accompanying Spinellane from the extinct volcanoes of the Rhine.

**DICHAIRITE.** *Iolite*, *Peliome*, *Steinheilite*, No. 305.

Haid., 3.1. Phil. 93. Haid. 2.319. Leon. 466.

Occurs in imbedded crystals, and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.

$M.M'$  nearly  $120^\circ$ . Cleavage parallel to the lateral planes. Fracture conchoidal. Hard. 7.0, 7.5. Sp.gr. 2.583. Transparent, translucent. Lustre vitreous. Colour blue in the direction of the axis, and yellowish-grey perpendicular to it; sometimes dull yellowish in both directions. Streak white.

*Massive varieties*, amorphous. Structure indistinctly granular.

Found in Spain, in Bavaria, in Finland, and other localities.

**DIPYRE.** *Leucolite*, No. 343.

Haid., 2.596. Phil. 45. Haid. 2.264. Leon. 475.

Occurs in small imbedded crystals.

Primary form not determined. Fracture conchoidal.

Hard. 5.0, 5.5. Sp.gr. 2.63. Opaque. Lustre internally vitreous. Colour greyish and reddish-white.

Found in the Western Pyrenees.

**DISULITE,** No. 344.

Occurs at Franklin, New Jersey, North America, in regular octahedral crystals imbedded in carbonate of lime.

Colour yellowish-brown. No published description or analysis. Possibly brown Spinelle.

**DOMITE,** No. 345.

Phil. 203.

Occurs in white, greyish, or yellowish, earthy or pulverulent, amorphous, masses, at Puy de Dome, in Auvergne.

**EDINGFORDITE,** No. 221.

E.J.S. 3.316. Leon. 731.

Occurs in attached crystals in the cavities of Thomsonite.

Primary form, according to Haidinger, a Square prism. Cryst. fig. 65. Cleavage parallel to the lateral planes. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 2.71. Translucent. Lustre vitreous. Colour greyish-white. Streak white.

Found in the neighbourhood of Dumbarton, Scotland.

**ELAEITE.** *Pettstein*, *Lythrodex*, *Sodaite* No. 238.

Mineralogy

Haüy, 4.505. Phil. 136. Haid. 3.93. Leon. 468.

Occurs in amorphous masses, with cleavages parallel to the lateral planes, and both the diagonals of a Rhombic prism of  $112^\circ$ . Fracture conchoidal. Hard. 5.5, 6.0. Sp.gr. 2.55, 2.62. Translucent. Lustre vitreo-resinous, sometimes fatty, occasionally opalescent. Colour greenish or bluish-grey, or greyish or brownish-red.

Found in Norway imbedded in Syenite.

EMERALD. *Beryl*. *Aquamarine*, No. 322.

Haüy, 2.504. Phil. 102. Haid. 2.316. Leon. 391.

Occurs in attached and imbedded crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 104^\circ 28'$ . Cleavage parallel to all the planes of a regular hexagonal prism, the form it generally assumes. Fracture uneven. Hard. 7.5, 8.0. Sp.gr. 2.68, 2.732. Transparent, translucent. Lustre vitreous. Colour various shades of green, blue, and yellow. Streak white.

*Massive varieties*, amorphous, structure large granular, or globular with a fibrous structure.

Found in Columbia, Peru, Brazil, North America, Siberia, and in several parts of Europe.

EPIDOTE. *Pistazite*. *Thallite*, No. 289.

Haüy, 2.568. Phil. 41. Haid. 2.282. Leon. 476.

Occurs in attached and imbedded crystals, massive and granular.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 103^\circ 10'$ .  $M, M' = 63^\circ 25'$ . Cleavage parallel to  $P$  and  $h$ , fig. 91. Fracture uneven. Hard. 6.0, 7.0. Sp.gr. 3.425, 3.45. Transparent to opaque. Lustre vitreous. Colour various shades of green, greenish-grey, brownish-yellow, and blackish-red. Streak greyish-white.

*Massive varieties*, amorphous. Structure granular, compact, fibrous. Occasionally arenaceous.

Found in many parts of Europe and America, and in the East Indies.

Thulite and Withamite have been referred to this species.

— EPISTILBITE, No. 214.

E.J.S. 4.286. Leon. 735.

Occurs in crystals attached to a mass of the same substance.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 135^\circ 10'$ . Cleavage parallel to the short diagonal of the prism. Fracture uneven. Hard. 4.5. Sp.gr. 2.25. Transparent, translucent. Lustre vitreous. Colour white. Streak white.

Found in Iceland and the Faroe Islands.

ERLANITE, No. 243.

Au. N.S. 8.389. Leon. 736.

Occurs massive and amorphous, forming a bed of 100 fathoms in thickness. Structure granular, compact. Fracture foliated, splintery. Hard. 5.5. Sp.gr. 3.0, 3.1. Opaque. Lustre very feeble. Colour greenish-grey. Streak white, shining.

Found in the Saxon Erzgebirge, near Erla

Used as a flux by iron smelters.

EUGLASE, No. 323.

Haüy, 2.528. Phil. 101. Haid. 2.313. Leon. 395.

Occurs in detached crystals in alluvial ground in Brazil.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 118^\circ 40'$ .  $M, M' = 114^\circ 50'$ . Cleavage parallel to the terminal plane, and horizontal

diagonal, indistinct, but very distinct parallel to the oblique diagonal. Fracture uneven. Hard.

Sp.gr. 3.098. Transparent. Lustre vitreous. Colour pale bluish-green, blue, and white. Streak white.

EUDYALITE, No. 329.

Phil. 122. Haid. 3.96. E.P.J. 12.81. Leon. 390.

Occurs in imbedded crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 73^\circ 40'$ . Cleavage parallel to  $a$ , fig. 107. and to  $p$ , fig. 121. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 2.9. Faintly translucent, opaque. Lustre vitreous, sometimes dull. Colour brownish-red. Streak white.

*Massive varieties*, imbedded and amorphous.

Found in Greenland.

FAHLUNITE. *Tricklasite*, No. 265.

Haüy, 3.140. Phil. 56. Haid. 3.97. Leon. 737.

Occurs in imbedded, regular, hexagonal prisms, and in amorphous masses. Cleavage perpendicular to the axis of the prism. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 2.66. Nearly opaque. Colour blackish, yellowish, and greenish-brown. Streak greyish-white.

Found at Fahlun in Sweden.

This has been described as a Right rhombic prism of  $109^\circ 28'$ , and it is said to be cleavable parallel to the lateral planes.

FELSPAR. *Orthose*, No. 226.

Haüy, 3.79. Phil. 113. Haid. 2.251. Leon. 424.

Occurs crystallized and massive.

Primary form an Oblique rhombic prism.  $P, M = 112^\circ 35'$ .  $M, M' = 118^\circ 58'$ . Cleavage parallel to the terminal plane and the oblique diagonal, distinct; less so parallel to  $M$  and  $M'$ . Fracture conchoidal, uneven. Hard. 6.0. Sp.gr. 2.5, 2.6. Transparent, translucent. Lustre vitreous. Colour white, grey, green, red, of different shades. Streak greyish-white.

*Massive varieties*, amorphous. Structure granular, compact. Sometimes in imbedded globular concretions. But it will probably be found that several distinct Minerals have been classed as compact felspar.

Found in all parts of the World.

FORSTERITE, No. 346.

Au. N.S. 7.59. Haid. 3.102. Leon. 739.

Occurs in attached, small, brilliant crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 128^\circ 54'$ . Cleavage parallel to  $P$ . Harder than quartz. Translucent. Lustre vitreous. Colour white.

From Vesuvius, accompanied by Plechaste and Pyroxene.

FREISLEBEN, No. 347.

Lucas, 2.216.

Is described as having a foliated fracture. Hard. about 3.0. Considerable lustre. Colour blue, sometimes greyish. Soft to the touch. Insoluble in water.

No locality or analysis given.

FUSCITE, No. 348.

Phil. 204. Leon. 474.

Is said by Phillips to be a Rhombic prism of  $87^\circ$  and  $93^\circ$ ; is considered by Haidinger to be Pyroxene, and by Leonhard to be Scapolite. It is, therefore, a doubtful species.

**Mineralogy** Found near Arendahl in Norway.  
**GABRONITE**, No. 232.  
 Phil. 132.

Occurs crystallized and massive. Primary form a Square prism. **CRYST.** fig. 65. Cleavage parallel to the lateral planes, indistinct. Fracture uneven. Hard. about 5.0. Sp.gr. 2.9. Opaque. Dull. Colour bluish or greenish-grey, red.

Found only in Norway.

**GARNET**. Precious, *Almandine*. Black, *Melanite*, *Pyreneite*. Greenish-yellow, *Grossularia*. Yellow, crystallized, *Topazolite*; granular, *Succinite*. Brownish-yellow, granular, *Colophonite*. Greenish, compact, *Allochromite*. Red, *Pyrope*, *Carbuncle*. Reddish-brown, *Essonite*, *Cinnamon-stone*, *Romanzovite*. Magnesian, *Rothoffite*, No. 294—301.

Probably some of these are distinct species, although their crystals are similar in form.

Haüy, 2.213. Phil. 26. Haid. 2.359. Leon. 487.

Occurs in attached and imbedded crystals of the form of rhombic dodecahedrons, granular and massive.

Primary form a Cube. **CRYST.** fig. 56. Cleavage parallel to the planes of the rhombic dodecahedron, very indistinct. Fracture uneven. Hard. 6.5, 7.5. Sp.gr. 3.6, 4.2. Transparent, translucent, rarely opaque. Lustre vitreous, resinous. Colour various shades and combinations of green, yellow, red, brown, black, white. Streak white.

*Massive varieties*, amorphous, structure granular, compact.

Found in most of the mountainous parts of the World.

**GEHLENITE**, No. 303.

Haüy, 2.557. Phil. 35. Haid. 3.102. Leon. 212.

Occurs in imbedded and massive aggregations of rectangular, or slightly rhombic crystals.

Primary form uncertain. Cleavage parallel to the planes of a rectangular or rhombic prism. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 3.029. Slightly translucent, opaque. Lustre slightly vitreous, resinous. Colour grey, sometimes yellowish or greenish.

Found only in the valley of Fassa in the Tyrol.

**GIESECKITE**, No. 264.

Phil. 113. Haid. 3.104. Leon. 461, 464, 465.

Occurs in imbedded crystals in the form of hexagonal prisms.

Structure of the crystals granular. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 2.832. Opaque. Lustre slightly resinous. Colour brownish-grey and greenish. Streak white.

Found in Greenland by Sir Charles Giesecké.

**GIGANTOLITE**, No. 349.

A name given by Nordenskiöld, on account of the size of the crystals, to a Mineral occurring in Finland, but first found at Schneeberg in Saxony, and then called *Pinite*. The Saxon specimens are decomposed, soft, and dull red. The Finland Mineral is not decomposed, and is dull dark green. Both varieties present the form of imperfect hexagonal prisms, and may be split into thin plates. The same substance has been found in North America, and named *Phyllite*.

**GLAUCOLITE**, No. 244.

P.M. and An. 2.463. Leon. 742.

Occurs massive. Structure crystalline. Cleavage parallel to the planes of a Rhombic prism, of about

107° or 143° 30', indistinct. Fracture uneven. **Mineralogy**  
 Hard. 5.0, 6.0. Sp.gr. 2.7, 3.2. Translucent.  
 Lustre vitreous. Colour lavender-blue, green.  
 Streak lighter.

Found near the lake Baikal in Siberia.

This Mineral affords an instance of the disadvantage of significant names, as at least three different substances, have been so called, merely on account of their colour, one of which, from Norway, has a cleavage parallel to the planes of the rhombic dodecahedron, and another has no apparent cleavage.

**GMELINITE**. *Hydrolite*, De Drée, No. 211.

Haüy, 3.177. Haid. 3.104. Leon. 742.

Occurs in attached crystals of the form of hexagonal prisms, lining cavities in trap rocks.

Primary form a Rhomboid. **CRYST.** fig. 106. Cleavage parallel to the primary planes. Fracture uneven. Hard. 4.5. Sp.gr. 2.05. Translucent. Lustre vitreous. Colour white, and pale dull yellow and red. Streak white.

Found in the Vicenti, in Ireland, and in North America.

### GOLD.

a. **NATIVE GOLD**, No. 17.

Haüy, 3.235. Phil. 322. Haid. 2.436. Leon. 707.

Occurs only in a metallic state, crystallized, and massive.

Primary form a Cube. **CRYST.** fig. 56. No cleavage. Fracture hackly. Hard. 2.5, 3.0. Sp.gr. 14.857. Opaque. Lustre metallic. Colour yellow, of several shades. Streak shining.

Found in North America, Mexico, Brazil, Peru, and other parts of South America, and in several parts of Europe, Asia, and Africa.

Native Gold is usually alloyed with a small quantity of silver. When the proportion is considerable the compound passes under the name of

b. **ELECTRUM**, No. 18.

**GREEN EARTH**, *Talc Zographique*, No. 257.

Haüy, 2.493. Phil. 117. Haid. 2.193. Leon. 199.

Occurs massive, imbedded in or lining the cavities of trap rocks. Fracture earthy. Hard. 1.0, 1.5. Sp.gr. 2.834. Opaque. Dull. Colour greyish, bluish, blackish-green. Streak shining.

Found in the Faro Islands, and in several parts of Europe, particularly near Verona, and generally wherever amygdaloidal rocks occur.

Several apparently different substances are so named on account of their colour and earthy fracture. Crystals of a green earthy substance of the form of *Pyroxene* are occasionally found in trap rocks.

**HARMOTOME**. *Andreolite*. *Ercinite*, No. 220.

Haüy, 3.142. Phil. 56. Haid. 2.229. Leon. 196

Occurs in attached crystals, generally intersecting each other lengthwise.

Primary form a Right rhombic prism. **CRYST.** fig. 71.  $M, M' = 110^\circ$ ; Levy. Cleavage parallel to the primary planes, and to both the diagonals of the prism. Fracture uneven. Hard. 4.5. Sp.gr. 2.35, 2.89. Transparent, translucent. Lustre vitreous, sometimes pearly. Colour greyish, yellowish, reddish-white. Streak white.

Found in Scotland, and in several places on the Continent of Europe.

The crossed crystals most commonly met with are

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from Andreasberg, and the simple ones from Strontian in Scotland.

**HARRINGTONITE**, No. 350.

A white substance so named from Ireland. It occurs in thin tabular masses, with a fine granular structure, and may possibly be only a variety of some known Mineral.

**HAÜYNE**, *Latialite*, No. 565.

Haüy, 2.335. Phil. 374. Haid. 3.107. Leon. 459. Occurs in attached dodecahedral crystals, granular, and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the diagonal planes of the cube, indistinct. Fracture uneven. Hard. 5.5, 6.0. Sp. gr. 2.68. Transparent to opaque. Lustre vitreous. Colour blue, sometimes greenish, white. Streak white.

*Massive varieties*, amorphous, structure granular, compact.

Found in the cavities of ancient lavas, and in the fragments of rocks ejected from Vesuvius.

**HEDENBERGITE**, No. 351.

Haüy, 4.495. Phil. 66. Leon. 506.

Is said by Phillips to measure the same as *Amphibole*; by Levy to be *Pyroxene*; by Berzelius to cleave into *oblique rhomboids*, similar to that of *carbonate of lime*; and by Haüy, into *octagonal prisms* with a base oblique to the axis. It is uncertain, therefore, to what Mineral the published descriptions really apply.

**HELVIN**, No. 302.

Haüy, 2.333. Phil. 244. Haid. 2.357. Leon. 462. Occurs in attached and imbedded tetrahedral or octahedral crystals.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron, indistinct. Fracture uneven. Hard. 6.0, 6.5. Sp. gr. 3.166. Translucent. Lustre vitreo-resinous. Colour dull yellow, sometimes brownish. Streak white.

Found at Schwarzenberg in Saxony.

**HERDERITE**, No. 352.

P.M. and An. 4.1

Occurs in imbedded crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 115^\circ 53'$ . Cleavage parallel to the lateral planes, and to the long diagonal of the prism. Fracture small conchoidal. Hard. 5.0. Sp. gr. 2.985. Nearly transparent. Lustre vitreous, slightly inclined to resinous. Colour yellowish and greyish-white. Streak white.

Found imbedded in Fluor at Ehrenfriedersdorf in Saxony.

**HERSCHELITE**, No. 353.

An. N.S. 10.361. Leon. 745.

Occurs in attached hexagonal crystals in the cavities of granular olivine.

Primary form a Rhomboid. Cryst. fig. 106.  $P, a$  about  $132^\circ$ . No perceptible cleavage. Fracture conchoidal. Hard. about 4.0. Sp. gr. 2.11. Translucent. Opaque. Colour white.

Found at Aci Reale in Sicily.

**HEULANDITE**, *Haydenite*, No. 215.

Haüy, 3.155. Phil. 38. Haid. 2.242. Leon. 745.

Occurs in attached crystals and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 106^\circ 1'$ .  $M, M' = 97^\circ 39'$ . Cleavage parallel to the oblique diagonal of the prism, very distinct. Fracture uneven. Hard. 3.5, 4.0.

Sp. gr. 2.2. Transparent, translucent. Lustre vitreous, on the cleavage planes pearly. Colour white, grey, yellow, red, brown. Streak white.

*Massive varieties*, granular.

Found principally in Iceland and the Faroe Islands, and generally lining cavities in trap rocks.

**HISINGERITE**, No. 172.

Phil. 204. Haid. 3.108. Lepn. 212, 746.

Occurs massive, with a distinct cleavage in only one direction, and an earthy fracture. Soft. Sp. gr. 3.045. Opaque. Colour black. Streak greenish-grey.

Found in Svärta Parish, Suderdtianland.

**HUMITE**, No. 354.

Bour. Cat. 52. Phil. 205. Haid. 3.110. Leon. 747. Occurs in attached crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 120^\circ$ . Cleavage parallel to  $M$  and  $M'$  distinct and bright. Fracture uneven. Hard. 6.5, 7.0. Transparent, translucent. Lustre vitreous. Colour brownish-yellow and light reddish-brown. Streak white.

Found on Monte Somma.

**HYALOSIDERITE**, No. 284.

Haid. 3.111. Leon. 533.

Occurs in imbedded crystals in a brown basaltic amygdaloidal rock.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 105^\circ$ ; W.P. Cleavage parallel to  $P$ . Fracture uneven. Hard. 5.5. Sp. gr. 2.875. Translucent, opaque. Lustre vitreous, superficially metallic. Colour reddish-brown. Streak light brown.

Found at Kaiserstuhl in Brisgaw.

The form and measurements of this Mineral agree very nearly with those of Olivine.

**HYPERSTHENE**, *Diallage metalloide*, var. *Labrador Hornblende*. *Paulite*, No. 285.

Haüy, 2.447. Phil. 70. Haid. 2.209. Leon. 516.

Occurs in crystalline masses, sometimes presenting parts of the natural surfaces of crystals. Cleavage parallel to the lateral planes of a rhombic prism of  $93^\circ 30'$ , and to both diagonals. Fracture uneven. Hard. 6.0. Sp. gr. 3.389. Opaque. Lustre metallic in one direction, on the cross fracture, vitreous. Colour on the metallic looking surface reddish, in other directions greyish or greenish-black. Streak greenish-grey.

*Massive varieties*, amorphous.

Found at Labrador, and in the Island of St. Paul.

This and the Bronzite and Schiller spar have the same cleavages and measurements.

**JADE**, *Igida*, its Indian name, *Axe stone*. *Beilstein*.

*Nephrite?* *Saussurite?* No. 306.

Haüy, 4.498. Phil. 134. Haid. 3.149. Leon. 423.

There is much uncertainty and confusion in the published description of Jade, Nephrite, and Saussurite; and it is not apparent what the Mineral is to which the name Igida has been applied in India. The Axe stone of the South Sea Islands appears to be a compact amianthus, or a serpentine enveloping a considerable quantity of amianthus. Werner's Jade or Beilstein is a brittle, yellowish-brown, fibrous Mineral. It is probable that the Chinese Jade is the substance which is also named Yu, and is believed to be Prehnite.

$\alpha$ . **NEPHRITE**, No. 307. This has been described as follows.

Haüy, 4.498. Phil. 134. Haid. 3.131. Leon. 764.

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## Mineralogy

Occurs massive. Structure *fibrous*, compact. Fracture splintery. Hard. 7.0. Sp.gr. 2.9, 3.02. Translucent, opaque. Colour green of several shades. Very tough.

Found in China, Egypt, and the Islands in the South Seas, where it is cut by the natives into various forms.

- b. SAUSSURITE, No. 308. This, which has been called by Haüy *Felspath tenace*, has also received the names *Jade*, *Aze stone*, &c. as synonyms, and is described as follows.

Haüy, 3.95. Phil. 135. Haid. 3.148. Leon. 422. Occurs massive. Structure *foliated*, granular. Cleavage parallel to the planes of a Rhombic prism of about  $124^\circ$ ; Haid. Fracture splintery. Hard. 5.5. Sp.gr. 2.25, 3.35. Nearly opaque. Lustre pearly. Colour greenish and greyish-white. Streak white.

Found in Corsica, Stiria, and some other places.

A more precise examination of these Minerals, and more distinct descriptions and analyses are necessary to a correct separation of the several varieties into more definite species. Specimens occur in Mineral cabinets under some or all of these names, which do not agree with any of the published descriptions.

IBERITE, No. 355.

An. 3.152.

Occurs in attached slender, four-sided prisms, with terminal faces obliquely truncated, and massive with a radiated structure.

Primary form not sufficiently described, and no measurements given. Cleavage parallel to the axis of the prism in two directions. Fracture uneven. Very soft. Translucent on the edges of the crystals. External lustre nearly dull, internal vitreous. Colour white. Adheres slightly to the tongue.

Found near Teflis in Georgia.

Is perhaps Lappmontite, or one of the already known members of the family of Zeolites, in a state of partial decomposition.

IDOCRASE. *Vesuvian. Wiluite. Egeran. Red, Frugardite. Greenish-yellow, Lohoute. Blue, Cyprine.* No. 291 to 293.

Haüy, 2.544. Phil. 33. Haid. 2.354. Leon. 483, 484. Occurs in attached and imbedded crystals, and massive.

Primary form a Square prism. Cryst. fig. 65. Cleavage parallel to the primary planes, distinct, and less so parallel to the diagonals of the prism. Fracture uneven. Hard. 6.5. Sp.gr. 3.08, 3.4. Transparent, translucent. Lustre vitreo-resinous. Colour several shades of grey, blue, green, yellow, brown, black. Streak white.

Massive varieties, amorphous. Structure fibrous, granular, compact.

- Found originally in the neighbourhood of Vesuvius, and since in many parts of Europe, and in Asia and America.

JEFFERSONITE, No. 273.

Haid. 3.115. Leon. 505, 506.

Has the form, measurements, and most other characters of Pyroxene.

Found near Sparta, New Jersey, North America.

ILMENITE, No. 356.

P.M. and An. 10.187. E.P.J. n.s. 3.187, 386.

Occurs in imbedded crystals in Cleavelandite.

Primary form a Right rhombic prism. Cryst. fig. 71.

M, M' =  $136^\circ 30'$ . No cleavage observed. Fracture uneven. Hard. 5.0. Sp.gr. 5.43. Opaque. Lustre vitreous. Colour black.

Found near Lake Ilmen in Siberia.

INDIANITE, No. 315.

Phil. 44. Haid. 3.113. Leon. 748.

Occurs in granular masses. Part of a fragment at the British Museum having afforded a measurement of  $95^\circ 15'$  on cleavage planes. Hard. 5.0, 5.5. Sp.gr. 2.74. Bournon. Translucent. Colour nearly white.

Found in the Carnatic in India.

## IRIDIUM.

a. OSMIURET OF IRIDIUM, No. 16.

Haüy, 3.231. Phil. 326. Haid. 3.114. Leon. 704. Occurs in loose hexagonal crystals, and flattened grains, accompanying native platina.

Primary form a Rhomboid. Cryst. fig. 106. P, P' not ascertained. Cleavage perpendicular to the axis, very distinct. Hard. 4.5, 5.0. Sp.gr. 19.5. Opaque. Lustre metallic. Colour pale steel-grey.

Found in South America and in the Uralian mountains.

## IRON.

## Aluminate of Iron?

a. SKORIAN, No. 149.

Breit. 88.

Occurs in amorphous masses, resembling a slag or scoria.

Primary form apparently a Rhombic prism. Cleavage uneven. Fracture conchoidal, uneven. Hard. 8.0, 8.5. Sp.gr. 3.7, 3.8. Lustre vitreous. Colour black.

Found at Bischoffstein in Bavaria and at Schandau in Saxony.

## Cubic Arseniate of Iron.

a. PHALMAKOSIDERIT, No. 469.

Haüy 4.135. Phil. 241. Haid. 2.162. Leon. 165.

Occurs in attached crystals, and sometimes massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the primary planes, indistinct. Fracture uneven. Hard. 2.5. Sp.gr. 3.0. Transparent, translucent, opaque. Lustre vitreous. Colour green of several shades, yellowish-red, yellowish and greenish-brown. Streak a paler colour.

Massive variety, amorphous; structure granular.

Found principally in Cornwall, also at St. Leonhard in France, at Schwartzenberg in Saxony, and at Franklin, North America.

## Rhombic Arseniate of Iron.

a. SKORODITE. Martial Arseniate of Copper of Bournon, No. 468.

Phil. 320, 321. Haid. 3.149. Leon. 166.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71. M, M' =  $120^\circ 10'$ . Phil. Cleavage parallel to the primary planes, indistinct. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 3.16, 3.2. Transparent, translucent, opaque. Lustre vitreous, brighter on the natural than the fractured surfaces. Colour bluish and blackish-green, brown, black. Streak white.

Massive varieties, globular, structure fibrous, radiating.

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Found in Cornwall, Saxony, Carinthia, and in more perfect crystals in Brazil.

Berzelius seems to consider the variety from Brazil as a distinct species, but as it agrees in measurement with the others, it is probable that the analysis of more perfect specimens would lead to a different conclusion.

*Arseniate of Iron ?*

- a. **PITTIZITE. Iron pitch ore ? Iron sinter ?** No. 470. Phil. 236. Haid. 3.115. Leon. 128.

Occurs in reniform and stalactitic masses. Structure compact. Fracture conchoidal. Soft. Sp.gr. 2.4. Translucent, opaque. Lustre vitreous. Colour brown of different shades.

Found in Saxony and Silesia.

An uncertain species, and probably comprehending several distinct Minerals, as specimens have been received in this Country under these names, differing from each other in all their physical characters.

- b. **Arsenite of Iron ?** No. 471.

Brit. Min. 5.275.

Described by Gregor as massive, compact to earthy. Lustre dull waxy. Colour dull bluish-olive-greens. Found in Cornwall.

*Carbonate of Iron.*

- a. **CARBONATE OF IRON. Brown Spar. Sphathose Iron. Sphärosiderit,** when botryoidal or globular, No. 452.

Haüy, 4.113. Phil. 236. Haid. 2.102. Leon. 296,7. Occurs in attached crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 107^\circ$ . Cleavage parallel to the primary planes, distinct. Fracture imperfect conchoidal. Hard. 3.5, 4.5. Sp.gr. 3.6, 3.829. Transparent, translucent, opaque. Lustre vitreous, inclining to pearly. Colour white, yellowish, and greenish-grey, yellow, red, and brown of different shades.

**Massive varieties,** tabular. Structure fibrous, the direction of the fibres nearly perpendicular to the flat surfaces; botryoidal and globular, structure fibrous, diverging; amorphous structure, foliated, granular, compact.

Found in Cornwall, Scotland, and Ireland, and in many metalliferous veins in other parts of Europe and in America.

*Argillaceous Carbonate of Iron.*

- a. **CLAY IRON STONE,** No. 453.

Haid. 2.408. Phil. 237. Leon. 235,6 ; 550,1.

The different clay iron stones appear to be carbonates of iron mixed with different proportions of silex, clay, and other foreign matters.

*Carburet of Iron.*

- a. **GRAPHITE. Black Lead. Plumbago,** No. 42.

Haüy, 4.85. Phil. 364. Haid. 2.191. Leon. 674.

Occurs in imbedded crystals of the form of regular hexagonal prisms, and massive. Primary form a Rhomboid. Cryst. fig. 106.  $P, P'$  unknown. Cleavage parallel to the terminal planes of the prisms, very distinct, and the laminæ flexible. Fracture uneven. Hard. 1.0, 2.0. Sp.gr. 1.8, 2.1. Opaque. Lustre metallic. Colour iron or steel-grey, or blackish-grey. Streak black, shining.

**Massive varieties,** in irregular nodules and amorphous. Structure foliated, granular, compact.

Found in various parts of Europe and America, and appears to be intimately related to Anthracite.

The finest kind found in this Country occurs at Borradale, in Cumberland.

The difference of composition between the foliated and granular varieties does not appear to have been ascertained.

- b. **SIDEROGRAPHITE,** No. 43.

Sill. 2.176. Leon. 716.

Resembles laminated plumbago. Sp.gr. 5.114. Magnetic. Consists of metallic iron and plumbago.

Found at Schooley's Mountain, New Jersey, North America.

*Chromate of Iron.*

- a. **CHROMATE OF IRON,** No. 420.

Haüy, 4.130. Phil. 240. Haid. 2.396. Leon. 557.

Occurs in imbedded octahedral crystals and grains, and massive. Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron. Fracture uneven. Hard. 5.5. Sp.gr. 4.0, 5.0. Opaque. Lustre imperfect metallic. Colour dark brown, black. Streak brown.

**Massive varieties,** amorphous. Structure granular, the grains sometimes separated by their partitions of talc coloured by chromic acid ; compact.

Found in Scotland, in the Shetland Islands of Unst and Fetlar ; in France, and other parts of Europe ; in Siberia, and near Baltimore, at Hoboken, New Jersey, and some other places in North America.

*Native Iron.*

- a. **Meteorite ?**

**AEROLITE. Meteorite,** No. 1.

Haüy, 3.531. Phil. 213. Haid. 2.442. Leon. 713.

Occurs disseminated in aerolites or meteoric stones, and in compact and vesicular masses, the cavities being sometimes filled with compact olivine. It is also said to have occurred crystallized in the form of the regular octahedron.

Primary form a Cube. Cryst. fig. 56. No apparent cleavage. Fracture hackly. Hard. 4.5. Sp.gr. 6.48, 7.768. Opaque. Lustre metallic. Colour pale steel-grey. Streak the same, shining.

Found in meteoric stones, in various parts of the World. In compact and vesicular masses in Siberia, Peru, Mexico, North America, the Cape of Good Hope, and in several parts of Europe. Knives of meteoric iron were found in possession of some of the Esquimaux Tribes in North America.

- b. **Terrestrial Native Iron,** No. 2.

Haüy, 3.531. Phil. 213. Haid. 2.442. Leon. 715.

Occurs massive in thin plates, ramose or cellular, sometimes covered by brown oxide of iron. Lustre metallic. Colour lighter than common iron.

Found near Grenoble in France, and at Steinbach, Eibestock, and Hamsdorf in Saxony.

S.J. 12.155. No. 3.

Occurs as a thin stratum, in a mass of mica slate, coated with crystalline graphite. Cleavage uncertain. Hardness the same as metallic iron. Sp.gr. 5.95, 6.72. Colour less silvery-white than meteoric iron. Malleable.

Found at Capaan, Connecticut, United States. Not alloyed with any other metal.

- c. **Terrestrial Native Iron containing Arsenic,** No. 4.

S.J. 14.183. Leon. 663

Cleavage parallel to planes inclining to each other at about  $120^\circ$ . Fracture hackly. Hardness nearly that of ordinary steel. Sp.gr. 7.837. Lustre of

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the cleavage planes highly metallic. Colour greyish, silver-white. Malleable.

Found in Bedford County, Pennsylvania, United States.

d. *Volcanic Native Iron*, No. 5.

Phil. 214.

Found in the Department of Puy de Dome in France, in a ravine formed by torrents across the lava and scorix of the mountain of Gravenoire.

e. *Terrestrial Native Steel?* No. 6.

S.J. 12.155.

Found with the native iron at Canaan, Connecticut, in small angular fragments. Structure granular. Scratches glass. Colour silvery white. Brittle.

f. *Volcanic Native Steel?* No. 7.

Phil. 214.

Found near La Bouiche, in the Department of Allier, France, near a coal mine which appeared to have undergone spontaneous combustion.

*Oxalate of Iron.*

a. *HUMBOLDTINE*, No. 591.

Haüy, 4.139. Phil. 242. Haid. 3.110. Leon. 789.

Occurs crystalline and massive. Primary form not ascertained. Soft. Sp.gr. 1.3. Opaque. Dull. Colour brightish yellow.

*Massive variety*, small, flattish, reniform pieces. Structure fine earthy.

Found near Bihm in Bohemia.

*Oxydulous Iron.*

a. *MAGNETIC IRON*, No. 126.

Haüy, 3.560. Phil. 221. Haid. 2.399. Leon. 554.

Occurs in attached and imbedded crystals, arenaceous and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron, distinct, but in some varieties not obtainable. Fracture conchoidal, uneven. Hard. 5.5, 6.5. Sp.gr. 4.4, 5.1. Opaque. Lustre metallic, occasionally bright. Colour iron-black. Streak black.

*Massive varieties*, amorphous. Structure granular to compact.

Found in several parts of North and South America and Europe, and in the East Indies and China.

Titanium is frequently contained in magnetic iron, but the varieties containing it have not hitherto been well distinguished.

*Oxide of Iron.*

a. *Crystallized and retaining the metallic lustre.*

*OLIGISTE IRON. Specular Iron. Micaceous Iron*, No. 125.

Haüy, 4.5. Phil. 224. Haid. 2.404. Leon. 545.

Occurs in attached crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106.  $P.P' = 86^\circ 10'$ . Cleavage parallel to the primary planes, and perpendicular to the axis. Fracture uneven, conchoidal. Hard. 5.5, 6.5. Sp.gr. 5.0, 5.251.

Opaque. Lustre metallic. Colour deep steel-grey to iron-black, frequently with a brilliant iridescent tarnish on the surface. Streak red, and reddish-brown. Slightly magnetic.

*Massive varieties*, amorphous, structure foliated.

Found in the Isle of Elba, and in many other parts of Europe. It also occurs in the lava of Auvergne in France, and in that of Vesuvius.

b. *Crystallized, but without metallic lustre, the crystals being very minute and thin, and frequently transparent*

*GOETHITE. Pyroxidate. Iron Froth.*

Mineralogy

The first of these varieties occurs in very thin, transparent, crystalline plates, in the cavities of black Hematite. The iron froth consists of very thin, brownish-red, scaly particles, which are slightly coherent, with a greasy feel, and staining the fingers. It is found plentifully in Devonshire and Lancashire, and generally accompanies other varieties of this species.

c. *Fibrous, compact, and earthy masses.*

*RED HEMATITE.*

Leon. 548.

1. Occurs in globular and botryoidal shapes. Structure fibrous, generally radiating. Sp.gr. 4.7, 5.0. Opaque. Sometimes with a metallic lustre externally; sometimes dull. Internally nearly dull. Colour externally bluish-grey, greyish-red, red; internally red. Streak red.

Found at Ulverstone in Lancashire, in considerable quantities, and in other parts of Great Britain and Europe.

2. Amorphous masses. Structure compact, and sometimes slaty. Sp.gr. 3.5, 5.0. Fracture conchoidal. Lustre and colour nearly the same as the preceding variety.

3. Red ochre. Red clay-iron-stone, generally found in compact and earthy masses. The distinguishing character is the shining red stain they produce on the fingers.

*Oxide of Iron, Zinc, and Manganese.*

a. *FRANKLINITE*, No. 127.

Phil. 226. Haid. 2.403. Leon. 551.

Occurs in attached crystals, granular and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron, very indistinct. Fracture conchoidal. Hard. 6.0, 6.5. Sp.gr. 4.87, 5.09. Opaque. Lustre metallic. Colour iron-black. Streak deep red-brown. Magnetic without polarity.

*Massive varieties*, amorphous. Structure granular, compact.

Found at Franklin, New Jersey, North America.

*Oxide of Iron and Lead.*

a. *BEUDANTITE*, No. 136

Am. N.S. 11.195. Leon. 722.

Occurs in small aggregated crystals.

Primary form a Rhomboid, Cryst. fig. 106.  $P.P' = 92^\circ 30'$ . Cleavage perpendicular to the axis. Hard. 4.0, 5.0. Nearly opaque. Lustre resinous. Colour black; in thin fragments deep brown. Powder greenish-grey.

Found at Horhausen on the Rhine.

Nepheline has also been named Beudantite.

*Hydrate of Iron.*

a. *HYDROUS OXIDE OF IRON. Brown Iron-ore. Stilpnosiderite?* No. 143.

Haüy, 4.101. Phil. 226. 230. Haid. 2.411. Leon. 230.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M.M' = 95^\circ 14'$ . Levy. Cleavage parallel to the short diagonal. Fracture uncertain. Hard. 5.0, 5.5. Sp.gr. 3.93. Nearly opaque. Lustre adamantine. Colour brown, of various shades. Streak yellowish-brown.

*Massive varieties*. Brown hematite, globular, reniform, and some of the varieties of brown and yellow clay-iron-stone. Stalactitic, structure fibrous, or fibro-



Mineralogy

laminar. Sometimes in pseudomorphous crystals.

Found in good crystals in Cornwall, and the other varieties in most parts of the World

*Oxide of Iron and Manganese?*

a. UMBER, No. 128.

Phil. 232. Haid. 3.186.

Occurs massive, amorphous. Structure earthy. Fracture conchoidal. Soft. Sp.gr. 2.2. Opaque. Dull. Colour yellowish and reddish-brown.

Found in the Isle of Cyprus.

*Phosphate of Iron.*

a. VIVIANITE, Blue Iron, No. 488.

Haid. 4.126. Phil. 238. Haid. 2.188. Leon. 137, 284. Occurs in attached crystals, in imbedded crystalline aggregations, and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 105^\circ 19'$ .  $M, M' = 108^\circ$ . Levy. Cleavage parallel to the oblique diagonal. Fracture indistinct. Hard. 1.5, 2.0. Sp.gr. 2.66, 2.70. Transparent, translucent. Lustre vitreous. Colour various shades of blue and green. Streak lighter colour.

Massive varieties, aggregations of crystalline particles, or globular and amorphous earthy masses.

Found crystallized in Cornwall, at Bodenmais in Bavaria, in Brazil, in New Jersey, North America, and in some other places.

The compact earthy varieties occur in several parts of Europe and America.

b. KARPHSIDERITE? No. 489.

E.J.S. 8.181.

Occurs in reniform masses. Structure granular, compact. Hard. 4.0, 4.5. Sp.gr. 2.5. Opaque. Lustre resinous. Colour pale and bright straw-yellow. Streak the same. Shining. Feels greasy. Much resembles iron sinter.

Found in Greenland.

*Scheelite of Iron and Manganese.*

a. WOLFRAM, No. 414.

Haid. 4.366. Phil. 255. Haid. 2.357. Leon. 343. Occurs in attached and imbedded crystals, massive, and pseudomorphous.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M' = 110^\circ 50'$ .  $M, M' = 101^\circ 5'$ . Cleavage parallel to the terminal plane and to both its diagonals, that through the oblique diagonal very distinct. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 7.1, 7.3. Opaque. Lustre imperfect metallic. Colour dark brown, brownish-black. Streak dark brown.

Massive varieties, amorphous, structure crystalline, columnar. The pseudomorphous crystals are octahedrons resembling those of Scheelite of lime.

Found very generally in tin mines, and in other veins in primitive rocks.

*Silicate of Iron.*

a. CRONSTEDTITE, No. 281.

Phil. 227. Haid. 3.90. Leon. 211.

Occurs in small, thin, attached hexagonal prisms, sometimes in radiating groups, and massive. Primary form a Rhomboid. Cryst. fig. 106. Cleavage perpendicular to the axis, distinct. Hard. 2.0, 2.5. Sp.gr. 3.348. Opaque. Lustre vitreous. Colour black and brownish-black. Streak dull green.

Massive variety, reniform. Structure fibrous.

Found near Przibram in Bohemia, and in Cornwall.

b. SIDEROSCHISOLITE, No. 175.

E.J.S. 2.371. Leon. 778.

Occurs in small three-sided and six-sided pyramids attached by their apex. Cleavage parallel to the base of the pyramids. The face of cleavage smooth, the planes of the pyramids convex. Hard. 2.0, 3.0. Sp.gr. probably above 3.0.

Supposed to be a variety of Cronstedtite by Dr. Werneking, but the description is too imperfect for an exact comparison.

Found at Conhonas do Campo. Brazil.

c. THRAULITE, No. 176.

E.J.S. N.S. 1.185.

Occurs in amorphous masses, accompanying iron pyrites, at Bodenmais, in Bavaria. Structure curved, foliated. Cross fracture uneven. Nearly opaque. Lustre vitreo-resinous. Colour brownish-black

d. NONTRONITE, No. 177.

E.J.S. 10.150.

Occurs in small nodules imbedded in an ore of manganese. Fracture earthy. Opaque. Dull. Colour pale yellow, sometimes greenish. Streak shining. Unctuous to the touch and very tender.

Found near the village of St. Pardoux, Arrondissement of Nontron, Department of Dordogne, France.

e. CHLOROPAL, No. 174.

Phil. 378. Haid. 3.85. Leon. 179.

Occurs massive, amorphous. Structure compact, sometimes earthy. Fracture conchoidal, uneven. Hard. 3.0, 4.0. Sp.gr. 1.8, 2.0. Opaque. Lustre of the compact variety dull resinous. Colour green, sometimes reddish-brown.

Found near Ungvár, in Hungary.

f. GREEN IRON- EARTH? No. 357.

Haid. 3.106. Leon. 237.

Occurs reniform, botryoidal, globular, and amorphous. Surface smooth. Structure thin fibrous, curved lamellar, compact, sometimes pulverulent. Lustre resinous. Colour green, of several shades. Streak yellowish-grey.

Found at Schneeberg, in Saxony, and is a very imperfectly determined species.

The specimens which have appeared in this Country as green iron-earth are yellowish-green, with a fine granular fracture.

*Silicate of Iron and Lime.*

a. YENITE. Ivaite, No. 280

Haid. 4.91. Phil. 24. Haid. 2.414. Leon. 528.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 61.  $M, M' = 111^\circ 30'$ . Cleavage parallel to the long diagonal of the prism. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 3.8, 4.0. Opaque. Lustre vitreous. Colour black, sometimes brownish or greenish. Streak the same.

Massive varieties, amorphous, structure columnar, compact.

Found principally at Rio la Marina, and Cape Calamita in the Isle of Elba, and in Silesia, Norway, Siberia, and North America.

*Sulphate of Iron.*

a. MELANTERITE. Green vitriol, No. 540.

Haid. 4.140. Phil. 240. Haid. 2.41. Leon. 112.

Occurs in attached crystals, massive, fibrous, and earthy, resulting from the decomposition of other Minerals.

Primary form an Oblique rhombic prism,  $P, M = 99^\circ$

Mineralogy

Mineralogy

20'.  $M, M' = 82^\circ 20'$ . Cleavage parallel to all the primary planes. Fracture conchoidal. Hard. 2.0. Sp.gr. 1.832. Transparent, translucent. Lustre vitreous. Colour green, of several shades, yellow, and yellowish-brown. Streak white. Taste sweetish and astringent.

*Massive varieties*, amorphous, structure granular, botryoidal, reniform, stalactitic. Structure fibrous; in thin fibres, filling the fissures of decomposing shale. Found in most mines in which sulphuret of iron occurs, and is frequently produced on the surface of cabinet specimens. It is also found in coal mines.

*Red Sulphate of Iron?*

a. BOTRYOGENE, No. 541.

E.J.S. 9.48.

Occurs in attached and aggregated crystals, the aggregations forming globular, botryoidal, and reniform shapes, with a crystalline surface.

Primary form an Oblique rhombic prism,  $P, M = 113^\circ 37'$ .  $M, M' = 119^\circ 56'$ . Cleavage parallel to  $M, M'$ , distinct, and indistinct parallel to another prism of  $81^\circ 44'$ . Hard. 2.25, 2.5. Sp.gr. 2.039. Translucent. Lustre vitreous. Colour deep yellowish-red, yellow. Streak yellow. Less soluble than green sulphate.

Found in the great copper mine at Fahlun in Sweden.

*Persulphate of Iron?*

a. MISY, No. 543.

E.J.S. 9.51.

Occurs in the form of a yellow crystalline powder at Fahlun in Sweden, and at Goslar in the Hartz.

*Cubic Sulphuret of Iron.*

a. IRON PYRITES, No. 72.

Haüy, 4.38. Phil. 217. Haid. 2.457. Leon. 657. Occurs in attached and imbedded crystals and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the primary planes, distinct, less so parallel to the planes of the regular octahedron. Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 4.60, 5.03. Opaque. Lustre metallic. Colour brass-yellow. Streak brownish-black.

*Massive varieties*, amorphous; structure granular, compact. Globular, and stalactitic; the surface drusy; structure fibrous or columnar, radiating. Occasionally in separate fibres.

Found in most parts of the World, and in some mining districts in great abundance.

It sometimes contains gold; and in Sweden, Bohemia, and Anglesey in this Country a pale yellow variety occurs in granular masses, containing selenium.

*Prismatic Sulphuret of Iron*

a. WHITE IRON PYRITES, No. 73.

Haüy, 4.68. Phil. 220. Haid. 2.462. Leon. 660. Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 106^\circ 2'$ . Cleavage parallel to  $M$  and  $M'$ , distinct. Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 4.678. Opaque. Lustre metallic. Colour pale whitish, greenish, or greyish-yellow. Streak greyish-black.

*Massive varieties*, botryoidal, reniform, stalactitic, and amorphous. Surface drusy. Structure diverging, fibrous, or columnar.

Found in most mining districts.

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*Magnetic Sulphuret of Iron.*

a. MAGNETIC IRON PYRITES, No. 74.

Haüy, 4.64. Phil. 221. Haid. 2.465. Leon. 665. Occurs in imbedded hexagonal crystals, and massive.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P'$  not ascertained. Cleavage parallel to all the planes of a regular hexagonal prism. Fracture uneven. Hard. 3.5, 4.5. Sp.gr. 4.631. Opaque. Lustre metallic. Colour pale yellowish and brownish-red. Liable to tarnish. Streak greyish-black.

*Massive varieties*, amorphous. Structure foliated, granular, compact.

Found crystallized, accompanying native silver in Norway and the Hartz. Massive in Cornwall, Wales, North America, Bavaria, Saxony, and many other places.

*Sulpho-arseniuret of Iron.*

a. MISPICKEL. Arsenical Iron, No. 111.

Haüy, 4.28. Phil. 215. Haid. 2.448. Leon. 663.

Occurs in attached or imbedded crystals and massive. Primary form a Right rhombic prism. Cryst. fig. 71.

$M, M' = 111^\circ 12'$ . Cleavage parallel to the primary planes. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 6.127. Opaque. Lustre metallic. Colour tin-white, sometimes with a yellowish tarnish. Streak greyish-black.

*Massive varieties*, amorphous. Structure columnar, granular, compact.

Found in most metallic veins in the older rocks.

*Sulphuret of Iron and Arsenic.*

a. HÜTTENBERGITE. Axotomous Arsenical Pyrites, No. 112.

Haid. 2.448.

Occurs crystalline and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.

$M, M' = 122^\circ 26'$ . Cleavage distinct, perpendicular to the axis of the prism. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 7.228. Opaque. Lustre metallic. Colour greyish-silver-white. Streak greyish-black.

*Massive varieties*, amorphous. Structure columnar, radiating, granular, fibrous? compact.

Found near Hüttenburg in Carinthia, at Reichenstein in Silesia, and at Schladming in Stiria.

*Titanate of Iron.*

A very indiscriminate class of iron ores, some crystallizing in Cubes and others in Rhomboids, and requiring a careful revision.

The following descriptions have been given of some of the varieties.

a. IRON SAND, No. 389.

Haid. 2.402. Leon. 365. 554.

There are so many loose, granular, and sandy varieties of iron ore found in alluvial soil, that no general description can be given which will comprehend them all. They generally contain titanium, but occasionally consist of magnetic or oligistic iron only.

b. ISERINE. In larger grains, containing about 28 per cent. of oxide of Titanium.

c. MENACCANITE. Containing about 45 per cent.

d. NIGRINE, No. 390.

Phil. 258. Haid. 2.376. Leon. 362.

Haidinger describes this as Rutile; but specimens received in this Country as Nigrine, are altogether different, and resemble Menaccanite in lustre, colour, and appearance of the fractured surfaces.

Mineralogy

Mineralogy

This may, therefore, be regarded as an uncertain species.

**e. AXOTOMOUS IRON, No. 391.**

Haid. 2.397. Leon. 366.

Primary form a Rhomboid. Cryst. fig. 106.  $P.P' = 85^\circ 40'$  nearly. Cleavage perpendicular to the axis, distinct. Fracture conchoidal. Hard. 5.0, 5.5. Sp.gr. 4.66. Opaque. Lustre imperfect, metallic. Colour black. Streak black.

Found at Gastein in Salzburg, in Sweden, and in Siberia.

**f. CRICHTONITE, No. 392.**

Haid. 4.98. Phil. 261. Haid. 2.399. Leon. 367. Occurs in attached crystals.

Primary form a Rhomboid. Cryst. fig. 106.  $P.P' = 61^\circ 20'$ , or  $85^\circ 40'$ , nearly, according to the planes assumed to be the primary, there being no apparent cleavage planes parallel to either set. Cleavage perpendicular to the axis. Fracture conchoidal. Hard. 4.5. Sp.gr. 4.0. Opaque. Lustre imperfect metallic. Colour black. Streak black.

Found at Oisans in France.

The cleavage and other characters render it probable that this may not differ chemically from the axotomous iron of Mohs.

**g. MOHSITE, No. 393.**

P.M. and An. 1.221.

Occurs in attached macled crystals.

Primary form a Rhomboid. Cryst. fig. 106.  $P.P' = 73^\circ 43'$ . No apparent cleavage. Fracture conchoidal. Hard. 5.5. Opaque. Lustre metallic. Colour black. Streak black. Not magnetic.

Found in Dauphiny, France.

**ISOPIRE, No. 310.**

P.M. and An. 3.70.

Occurs in amorphous masses in granite. Fracture conchoidal. Hard. 5.5, 6.0. Sp.gr. 2.912. Nearly opaque. Lustre vitreous. Colour black, or greyish-black, sometimes dotted with red. Streak greenish-grey. Slightly magnetic.

Found in the Western part of Cornwall, where it had been called black opal.

**ITTNERITE, No. 241.**

Leon. 749.

Occurs crystallized in Rhombic dodecahedrons and massive. Structure compact. Fracture uneven. Hard. 5.5. Sp.gr. 2.3. Lustre resinous to vitreous. Colour grey of different shades.

Found at Kaiserstuhl in Swabia.

**KAKOXENE, No. 503.**

E.J.S. 5.163. Leon. 749.

Occurs in thin fibrous radiating tufts or plates filling narrow fissures in a clayey-brown ironstone at Zbirow in Bohemia. Colour yellow of several shades and sometimes brownish-red.

**KARPHOLITE, No. 312.**

Phil. 22. Haid. 3.116. Leon. 209.

Occurs in slender crystals and silky fibres.

Primary form unknown. Sp.gr. 2.955. Lustre of the crystals vitreous, of the fibrous masses silky. Colour yellow, sometimes pale.

Found at Schlackenwalde in Bohemia.

**KEFFEKILLITE, No. 358.**

Leon. 181.

A Mineral from the Crimea, so named by Fisher of Moscow, not analyzed or described.

**KILLINITE, No. 223.**

Phil. 322. Haid. 3.117. Leon. 750.

Occurs in imbedded imperfect crystals and massive.

Cleavage parallel to the lateral planes and short diagonal of a rhombic prism of about  $135^\circ$ . Phil. Fracture uneven. Hard. 4.0. Sp.gr. 2.698. Translucent, opaque. Lustre dull vitreous. Colour brownish or yellowish-green, or greenish-grey. Streak yellowish-white.

Massive variety, amorphous, structure columnar, promiscuously arranged.

Found at Killiney near Dublin, Ireland.

**KNEBELITE, No. 288.**

Phil. 206. Haid. 3.118. Leon. 751.

Occurs massive, with a cellular and uneven surface.

Fracture imperfectly conchoidal. Hard. Brittle. Difficultly frangible. Sp.gr. 3.714. Opaque. Lustre glistening. Colour grey, with spots of dirty white, brownish-red, brown, and green.

No locality given.

**LABRADORITE. Labrador Felspar. Felspath Opaline, No. 234.**

Haid. 3.94. Phil. 115. Haid. 2.257. Leon. 430.

Occurs in rolled or imbedded crystalline masses.

Cleavage parallel to all the planes of a Doubly oblique prism. Cryst. fig. 95.  $P.M = 93^\circ 55'$ .  $P.T = 114^\circ 26'$ .  $M.T = 120^\circ 40'$ . Fracture uneven. Hard. 5.5, 6.5. Sp.gr. 2.69, 2.76. Translucent. Lustre vitreous. Colour grey, white, with rich iridescent colours in particular directions.

Found principally in rolled masses on the coast of Labrador, and in Devonshire imbedded in a trap rock. The white variety, which may possibly be Cleavelandite, is from Greenland.

The above measurements, which were taken on distinct but not bright cleavage planes, approach so very nearly to those of Cleavelandite as to create a doubt whether they really differ.

**LATROBITE. Diopside. Amphodolite? No. 316.**

Phil. 350. Haid. 3.118. Leon. 465.

Occurs in attached and imbedded crystals and massive.

Primary form a Doubly oblique prism. Cryst. fig. 95. Measuring  $91^\circ$ ,  $93^\circ 30'$ , and  $98^\circ 30'$ , nearly. Cleavage parallel to all the primary planes. Fracture uneven. Hard. 5.0, 6.0. Sp.gr. 2.72, 2.8. Translucent. Lustre vitreous. Colour pale red.

Found at Amitok Island, Labrador, and in Finland.

**LAUMONITE, No. 217.**

Haid. 3.151. Phil. 45. Haid. 2.284. Leon. 200.

Occurs in attached and aggregated crystals and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P.M = 113^\circ 30'$ .  $M.M' = 86^\circ 15'$ . Cleavage parallel to  $M.M'$ , distinct. Fracture uneven. Sp.gr. 2.2. Translucent, opaque. Lustre vitreous. Colour greyish, yellowish, reddish-white. Streak white.

Massive varieties, amorphous, structure granular. By exposure to the air it loses its water of crystallization, and becomes friable.

Found at Huelguet in Brittany, in Hungary, Faroe, Iceland, Scotland, and Ireland.

**LAVA, No. 250.**

Leon. 181. 413.

Occurs as a volcanic product in more or less compact or vesicular masses. Fracture uneven. Hardness and Sp.gr. variable. Translucent, opaque. Lustre vitreous. Colour greyish and greenish-black, brown, red, grey.

Mineralogy

**Mineralogy** Found at Vesuvius, Etna, and other volcanos.

**LAZULITE.** *Lapis Lazuli*, No. 564.

Haüy, 3.54. Phil. 44. Haid. 2.288. Leon. 136.460. Occurs in imbedded dodecahedral crystals and massive. Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the rhombic dodecahedron, indistinct. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 2.76, 2.94. Translucent, opaque. Lustre vitreous. Colour blue of different shades. Streak paler blue.

*Massive varieties.* Amorphous, sometimes in small imbedded grains; structure fine granular, compact. Brought from Persia and China, but neither its locality nor its geological relations are known.

Used in the manufacture of ultramarine, and in jewelry, as ornamental stones

### LEAD.

#### *Abiminate of Lead.*

a. **PLOMBGOMME**, No. 151.

Haüy, 3.410. Phil. 338. Haid. 2.140. Leon. 229. Occurs in small globular and reniform masses, composed of thin concentric layers. Structure of the layers indistinctly fibrous. Fracture uneven. Hard. 4.5, 5.0. Translucent. Colour yellow, sometimes brownish.

Found at Huelguet in Brittany.

#### *Arsenate of Lead.*

a. **GORLANDITE.** *Blumiere* when in reniform masses, No. 475.

Haüy, 3.355. Phil. 345. Haid. 2.133. Leon. 272. Occurs in attached crystals, in the form of regular hexagonal prisms, frequently with convex lateral planes, and massive.

Primary form a Rhomboid. Cryst. fig. 106. Cleavage parallel to the lateral planes of the hexagonal prism. Hard. 4.0, 5.0. Sp.gr. 5.0, 6.4. Transparent, translucent. Lustre resinous. Colour pale dull yellow, yellowish and reddish-brown.

*Massive varieties*, reniform, structure compact. Fracture conchoidal. Sp.gr. 3.9. Opaque. Lustre resinous. Colour brownish-red. From Nertschinsk in Siberia.

Found in Cornwall, at St. Prix in France, and in a few other places.

b. **ARSENITE OF LEAD** ! No. 476.

Specimens of a pale yellow substance in fine fibres, soft, and easily reducible to an impalpable powder, have passed under this name, but we do not find any published account of it.

#### *Carbonate of Lead.*

a. **CARBONATE OF LEAD**, No. 458.

Haüy, 3.365. Phil. 338. Haid. 2.130. Leon. 290. Occurs in attached crystals, in aggregations of columnar crystals, and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M:M' = 117:14$ . Cleavage parallel to all the primary planes. Fracture conchoidal. Hard. 3.0, 3.5. Sp.gr. 6.465. Transparent, translucent. Lustre adamantine on the cleavage planes, resinous on the fracture surfaces. Colour generally white, occasionally grey, yellow, green, black. Streak white. *Massive varieties*, amorphous; structure columnar, granular, compact.

Found in most lead mines, and occasionally in those of other metals, in many parts of Europe, Asia, and America, and used as an ore of lead.

### *Chloride of Lead.*

a. **CHLORIDE OF LEAD**, No. 63.

Occurs in small, thin, flat, white, opaque crystals, accompanying murio-carbonate of lead from Cornwall.

b. **CHLORO-CARBONATE OF LEAD.** *Murio-carbonate of Lead*, No. 65.

Haüy, 3.374. Phil. 343. Haid. 2.150. Leon. 204. Occurs in attached crystals.

Primary form a Square prism. Cryst. fig. 65. Cleavage parallel to the primary planes, distinct. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 6.0. Transparent. Lustre adamantine. Colour white, pale grey, yellow, and green. Streak white.

Found at Matlock, Derbyshire, and in Cornwall.

c. **BERZELITE.** *Chloro-oxide of Lead*, No. 64.

Haid. 2.151. Leon. 416.

Occurs in crystalline amorphous masses. Cleavage parallel to the lateral planes, and short diagonal of a rhombic prism of  $102^{\circ} 30'$ . Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 7.077. Translucent. Lustre adamantine. Colour yellowish-white, pale yellow, and red.

Found near Churchill, in the Mendip Hills, Somersetshire.

### *Chromate of Lead.*

a. **CHROMATE OF LEAD**, No. 421.

Haüy, 3.357. Phil. 349. Haid. 2.137. Leon. 337. Occurs in attached crystals and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P:M = 99^{\circ} 10'$ .  $M:M' = 93^{\circ} 30'$ . Cleavage parallel to the primary planes, indistinct. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 6.004. Transparent, translucent. Lustre adamantine. Colour red. Streak orange-yellow.

*Massive varieties*, amorphous; structure columnar, granular.

Found principally at Berezof in Siberia, and recently in Brazil.

### *Chromate of Lead and Copper*

a. **VAUQUELINITE**, No. 422.

Phil. 350. Haid. 3.167. Leon. 339.

Occurs in minute attached crystals, and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 5.5, 5.78. Nearly opaque. Lustre adamantine. Colour greenish-black, black. Streak greenish.

*Massive varieties*, botryoidal, reniform, amorphous; structure fine granular, compact.

Found at Berezof in Siberia, with chromate of lead.

### *Molybdate of Lead.*

a. **CARINTHITE**, No. 417.

Haüy, 3.397. Phil. 346. Haid. 2.140. Leon. 340.

Occurs in attached crystals and massive.

Primary form a Square prism. Cryst. fig. 65. Cleavage parallel to the primary planes, and to those of *Mod. c.* Cryst. fig. 68. Fracture uneven. Hard. 3.0. Sp.gr. 6.760. Transparent, translucent. Lustre resinous. Colour yellow of different shades, greenish-red, and red.

Found chiefly in Carinthia, also in Austria, Hungary, and in North America. The red at Moldawa in the Bannat.

### *Oxide of Lead with Molyb. Carb. Mur. Phosp. and Chromic Acids.*

a. **PAMPLONITE**, No. 418.

E.N.P.J. 12.142.

Occurs in small amorphous concretions in a decom-

## Mineralogy

posed syenite. Heavy. Sp.gr. 6.0. Colour greenish-yellow.

Found in the Puramo Rico, near Pamplona, South America.

*Native Lead.*

## a. NATIVE LEAD, No. 10.

Phil. 332. Haid. 3.129. Leon. 695.

Occurs in small, amorphous, imbedded masses in lava or some other fused substances. Fracture hackly. Hard. 1.5. Sp.gr. 11.35. Opaque. Lustre metallic. Colour lead-grey. Streak shining.

Found in Madeira and some other places, and at Alston in Cumberland.

*Red Oxide of Lead.*

## a. NATIVE MINUM, No. 135.

Hauy, 3.352. Phil. 337. Leon. 559.

Occurs in compact and pulverulent amorphous masses, supposed to arise from the decomposition of galena. Hard. 2.0, 2.5. Sp.gr. 4.6. Dull. Colour bright red.

Found in Yorkshire, in Swabia, Siberia, and some other places.

*Yellow Oxide of Lead.*

## a. NATIVE MASSICOT, No. 134.

An. 5.47. Leon.

Occurs in amorphous masses. Fracture earthy. Brittle. Sp.gr. 8.0. Opaque. Dull externally, internally semi-metallic. Colour yellow.

Found at Eschweiler.

*Phosphate of Lead.*

## a. PYROMORPHITE, No. 493.

Hauy, 3.385. Phil. 314. Haid. 2.133. Leon. 272.

Occurs in attached crystals, generally in the form of regular hexagonal prisms, frequently with the lateral planes convex, sometimes slender and fasciculated; and massive.

Primary form a Rhomboid. Cryst. fig. 106. Cleavage parallel to all the planes of the prism, and to the truncation of its terminal edges. Fracture uneven. Sp.gr. 7.098. Transparent, translucent. Lustre resinous. Colour grey, green, brown.

*Massive varieties*, globular, reniform, botryoidal; structure fibrous. Amorphous structure fibrous, granular, compact.

Found in most lead mines.

## b. PHOSPHATO-ARSENATE OF LEAD, No. 494.

Hauy, 3.385. Phil. 345. Haid. 2.133. Leon. 272.

Occurs in attached and aggregated crystals similar in form and most other characters to phosphate. Colour various shades of yellow.

*Scheelite of Lead.*

## a. SCHEELITE OF LEAD, No. 415.

Phil. 350. Haid. 3.165. Leon. 345.

Occurs in attached and aggregated crystals.

Primary form a Square prism, (Cryst. fig. 65,) of the same dimensions as that of Molybdate of lead. Cleavage perpendicular to the axis of the prism, and parallel to planes of *Mod. c*, Cryst. fig. 68. Fracture conchoidal. Hard. 3.0. Sp.gr. 8.0. Translucent. Lustre resinous. Colour yellowish and brownish-grey.

Found at Zinnwald in Bohemia, and Bleiberg in Carinthia.

*Seleniuret of Lead.*

## c. SELENIURET OF LEAD, No. 47.

An. N.S. 10.233, 284. Leon. 590.

Occurs in amorphous masses; structure granular, and

nearly resembling fine-grained galena. Softer than galena. Sp.gr. 7.697. Opaque. Lustre metallic, rather dull. Colour more blue than galena.

Found at Clausthal and Tilkrode in the Hartz, accompanied by some of the following varieties.

b. *Seleniuret of lead and cobalt*, No. 48.

c. . . . . *copper*, No. 49.

d. *Cupriferous seleniuret of lead*, No. 50.

e. *Seleniuret of lead and mercury*, No. 51.

f. . . . . *copper and silver*, No. 52.

These are said to resemble seleniuret of lead so nearly as to be scarcely distinguishable from it.

*Sulphate of Lead.*

## a. ANGLESITE, No. 548.

Hauy, 3.402. Phil. 346. Haid. 2.142. Leon. 249.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M.M' = 103^\circ 42'$ . Cleavage parallel to the primary planes. Fracture conchoidal. Hard. 2.5, 3.0. Sp.gr. 6.298. Transparent, translucent. Lustre approaching to adamantine. Colour white, sometimes greyish, yellowish, greenish, grey, and brown of several shades, black. Streak white.

*Massive varieties*, amorphous, structure laminar, granular, compact.

Found in lead and copper mines at Lead hills, Scotland, in Anglesey, in Cornwall, the Hartz, and other places in Europe, and in North America.

*Cupreous Sulphate of Lead*

## a. LINARITE, No. 549.

Phil. 347. Haid. 2.143. Leon. 251. P.M. and An. 10.267.

Occurs in attached crystals.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P.M = 96^\circ 25'$ .  $M.M' = 61^\circ$ . Cleavage parallel to P, and to the horizontal diagonals of the terminal planes. Fracture uneven. Hard 2.5, 3.0. Sp.gr. 5.3, 5.43. Transparent, translucent. Lustre adamantine. Colour deep blue. Streak pale blue. Found at Linares in Spain, and at Lead hills, Scotland.

*Sulphate and Carbonate of Lead.*a. LANARKITE. *Sulphato carbonate of Lead*, No. 550.

Phil. 341. Haid. 2.148. Leon. 253.

Occurs in long, slender crystals, single or aggregated into fibrous masses.

Primary form an Oblique rhombic prism, the angles of which have not been ascertained. The crystals are lengthened in the direction of the horizontal diagonals of the terminal planes. Hard. 2.0, 2.5. Sp.gr. 6.8, 7.0. Transparent, translucent. Lustre nearly resinous, but pearly on the cleavage planes. Colour greenish, yellowish, or, greyish. Streak white.

Found at Lead hills in Scotland.

b. CALDONITE. *Cupreous-sulphato-carbonate of Lead*, No. 551.

Phil. 342. Haid. 2.149. Leon. 254.

Occurs in attached crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M.M' = 95^\circ$ . Cleavage parallel to the primary planes, and to the short diagonal of the prism. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 6.4. Transparent, translucent. Lustre resinous. Colour blue and greenish-blue. Streak bluish or greenish-white.

Found at Lead hills in Scotland.

Mineralogy c. SUZANNITE. *Sulphato-tri carbonate of Lead*, No. 552. Phil. 341. Haid. 2.144. Leon. 252.

This Mineral occurs, as carbonate of lime does, under two forms. One an Acute rhomboid, Cryst. fig. 106,  $P, P' = 72^\circ 30'$ ; and the other a Right rhombic prism, Cryst. fig. 71,  $M, M' = 120^\circ$ .

Mr. Haidinger has regarded this last as an *Oblique* rhombic prism, a difference of opinion which may perhaps be explained by his own observations on Mr. Levy's *Humboldtite*; the compound figures given by him in *Edinb. Phil. Trans.* 10.217. being purely imaginary.

The cleavage of both forms is perpendicular to the axis, and very distinct. Hard. 2.5. Sp.gr. 6.3. Transparent, translucent. Colour grey-brown, yellow, green of various shades. Streak white.

Found at Lead hills in Scotland.

*Sulphuret of Lead.*

a. GALENA, No. 83.

Haüy, 3.341. Phil. 332. Haid. 3.13. Leon. 625. Occurs in attached crystals, and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the primary planes. Fracture conchoidal. Hard. 2.5. Sp.gr. 7.568. Opaque. Lustre metallic. Colour lead-grey. Streak the same.

*Massive varieties*, amorphous, structure granular, compact.

Found abundantly in many places in Europe, Asia, and America.

Sulphuret of lead is occasionally found to contain antimony, arsenic, silver, bismuth, and copper.

*Sulphuret of Lead, Antimony, and Copper.*

a. BOURNONITE. *Endellione. Triple Sulphuret*, No. 97. Phil. 336. Haid. 3.5. Leon. 613.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 93^\circ 30'$  nearly. Cleavage parallel to the primary planes, and to both the diagonals of the prism. Fracture uneven. Hard. 2.5, 3.0. Sp.gr. 5.763. Opaque. Lustre metallic. Colour approaching to steel-grey, sometimes blackish-grey. Streak the same.

*Massive varieties*, amorphous, structure granular, compact.

Found in Cornwall, and in several parts of Europe, and in Peru.

*Vanadate of Lead.*

a. JOHNSTONITE, No. 484.

E.J.S. n.s. 5.166.

Occurs in attached hexagonal crystals, and small globular concretions, frequently sprinkled over a surface of Calamine.

Primary form a Rhomboid. Cryst. fig. 106. Fracture conchoidal. Sp.gr. 6.99, 7.23. Translucent. Opaque. Lustre of the fractured surface resinous. Colour yellow, and reddish-brown. Streak white. Found at Waulockhead in Scotland.

LEELITE, No. 317.

Phil. 21. Haid. 3.119. Leon. 757.

Occurs in amorphous masses.

Structure compact. Fracture conchoidal. Sp.gr. 2.7. Slightly translucent. Lustre waxy. Colour flesh-red.

Found at Gryphytta in Sweden, and, when first discovered, passed under the name of red hornstone.

LEUCITE. *Amphigene*, No. 233.

Haüy, 3.61. Phil. 107. Haid. 2.220. Leon. 435.

Occurs in imbedded trapezohedral crystals, and massive.

Primary form a Cube. Cleavage parallel to the planes of the cube and rhombic dodecahedron. Fracture conchoidal. Hard. 5.5, 6.0. Sp.gr. 2.483. Transparent to opaque. Lustre vitreous. Colour greyish, yellowish, or reddish-white, and different shades of grey. Streak white.

*Massive variety*, amorphous, structure granular.

Found in the lavas of Vesuvius, and the basalts of Italy and Bohemia.

LEVYNE, No. 206.

Haid. 3.120. Leon. 758.

Occurs in attached crystals, lining cavities in trap rocks.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 79^\circ 29'$ . Cleavage parallel to the primary planes. Fracture conchoidal. Hard. 4.0. Sp.gr. 2.15. Translucent. Lustre vitreous. Colour white. Streak white.

Found at Dalsnypen in Faroe, in Ireland, and in a few other places.

It is said by Berzelius to be a variety of *Chabasie*.

LHERZOLITE, No. 359.

Gal. 168. Leon. 505.

Occurs in imperfectly formed crystalline grains, imbedded in greenish-yellow steatite. Sp.gr. 3.54. Transparent. Colour emerald-green.

Found on the banks of Lake Lherz, in the mountains Du Couserans, Pyrenees.

LIGURITE, No. 318.

Phil. 207. Haid. 3.121. Leon. 758.

Occurs in imbedded crystals in a talcose rock.

Primary form an Oblique rhombic prism. Cryst. fig. 63.  $M, M' = 140^\circ$ . Fracture uneven. Hard. 5.0, 6.0. Sp.gr. 3.49. Transparent, translucent. Lustre vitreo-resinous. Colour yellowish-green. Streak greyish-white.

Found on the banks of the Stura in the Apennines. Specimens of yellowish-green Sphene have been brought to this Country as Ligurite. This, however, cannot be the Mineral examined by Viviani, if his analysis be correct; for his Mineral does not contain a particle of titanic acid, of which Sphene contains from 33 to 40 per cent.

LIMBILITE, No. 360.

Phil. 208. Leon. 533.

Occurs in irregular grains in the volcanic hill of Limbourg. Structure compact. Hard. 6.0, 7.0. Colour honey-yellow.

## LIME.

### *Arsenate of Lime.*

a. PHARMACOLITE, No. 466.

Haüy, 1.587. Phil. 178. Haid. 3.135. Leon. 160. E.J.S. 3.302, 6.317.

Occurs generally in small, silky tufts, or minute globular and botryoidal fibrous masses, coating other substances, and very rarely in attached crystals.

*Crystallized.*

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $M, M' = 117^\circ 24'$ . Cleavage parallel to the oblique diagonals of the terminal planes. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 2.730.

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Transparent, translucent. Lustre vitreous. Colour yellowish-white. Streak white. Thin laminae are flexible.

Locality unknown.

*Fibrous.*

Very soft. Sp.gr. 2.64. Translucent, opaque. Lustre vitreous, pearly, dull. Colour white, greyish and reddish-white.

Found at Andreasberg, Hartz, in Thuringia, and some few other places.

## b. HAIDINGERITE, No. 467.

E.J.S. 3.303. 6.317. Leon. 160.

Occurs in attached crystals, and in pearly, botryoidal, crystalline coats.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 100^\circ$ . Cleavage parallel to the short diagonal of the terminal planes, very distinct. Hard. 2.0, 2.5. Sp.gr. 2.848. Transparent, translucent. Lustre vitreous. Colour white. Streak white. Thin laminae slightly flexible.

Locality unknown.

*Boro-silicate of Lime.*

## a. DATHOLITE, No. 426.

Haüy, 1.590. Phil. 177. Haid. 2.222. Leon. 285.

Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 73.  $M, M' = 103^\circ 40'$ . Phil. Cleavage parallel to the lateral planes, very indistinct. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 2.989. Translucent, opaque. Lustre vitreous, that of the fracture surfaces slightly resinous. Colour greyish, yellowish, greenish-white. Streak white.

Massive variety, amorphous, structure granular.

Found at Arendal in Norway.

## b. HUMBOLDTITE, No. 427.

Phil. 380. Haid. 2.222. Leon. 286. 789.

Occurs in attached crystals.

Primary form an Oblique rhombic prism. Cryst. fig. 88. P, h, fig. 91 =  $91^\circ 41'$ .  $M, M' = 115^\circ 45'$ . Levy. Cleavage parallel to the oblique diagonal of the prism. Fracture conchoidal. Hard. 4.5, 5.0. Sp.gr. 2.99. Transparent, translucent, opaque. Lustre vitreous. Colour white, sometimes yellowish. Streak white.

Found in the Tyrol, in the Hartz, in North America, and in the neighbourhood of Edinburgh.

It is probable that this will be found to correspond with *Datholite* in form and measurement, as it does in chemical composition; and that Mr. Levy has been deceived by the imperfection of the crystals he examined.

## c. BOTRYOLITE, No. 428.

Haüy, 1.591. Phil. 177. Haid. 2.222. Leon. 287.

Occurs in reniform, globular, and botryoidal masses.

Structure fibrous, in concentric coats. Sp.gr. 2.8. Translucent on the edges, sometimes opaque and earthy. Colour pale yellowish and reddish-grey, occasionally black on the surface. Streak white.

Found at Arendal in Norway.

*Rhomboidal Carbonate of Lime, No. 441.*

## I. Crystallized.

a. CALCITE. *Calcareous Spar. Iceland Crystal.*

Haüy, 1.298. Phil. 147. Haid. 2.83. Leon. 309.

Occurs in attached and imbedded crystals and crystalline masses, and occasionally stalactitic.

Primary form a Rhomboid. Cryst. fig. 106. P, P' =  $105^\circ 5'$ . Cleavage parallel to the primary planes,

very distinct. Fracture conchoidal, seldom observable. Hard. 3.0. Sp.gr. 2.721. Transparent, translucent. Lustre vitreous. Colour generally white, occasionally grey, blue, green, yellow, red, brown, black. Streak white, or slightly coloured.

Found in veins and in rocks of every formation in all parts of the World.

## 2. Foliated.

a. SCHIEFERSPAR. *Slate Spar.*

Haüy, 1.430. Phil. 149. Haid. 2.83. Leon. 316.

Occurs massive. Structure laminar, the laminae being thin and generally curved or wavy. Sp.gr. about 2.5. Translucent. Lustre vitreous on the edges, pearly on the surface of the laminae. Colour white, sometimes reddish, yellowish, greenish. Streak white.

Found in England, Scotland, Ireland, and in other parts of the World.

## 3. Pearly.

a. APHRITE. *Ecume de Terre. Schaumerde.*

Phil. 150. Haid. 3.72. Leon. 776.

Occurs in thin, white, pearly scales or plates. Hard. 0.5, 1.0. Sp.gr. 2.5. Opaque. Lustre pearly in a high degree. Colour white. Streak white.

Found in Saxony, Hessa, and some other places.

## 4. Columnar.

a. ANTHRACONITE. *Madrepore.*

Haüy, 1.358. Phil. 160. Haid. 2.83. Leon. 317.

Occurs in roundish masses. Structure columnar, diverging. Hard. 3.0. Sp.gr. 2.7. Opaque. Lustre vitreous. Colour greyish-black.

Found in Norway, Sweden, Greenland, and one or two other places.

## 5. Fibrous.

## a. STALACTITE.

Haüy, 1.364. Phil. 151. Haid. 2.83. Leon. 319.

Occurs reniform, stalactitic, tubular, and in other imitative shapes. Structure fibrous. Translucent, opaque. Lustre resinous, waxy, sometimes silky. Colour white with shades of grey, brown, red, yellow, and other colours. Streak whitish.

Found in fissures and caverns, in calcareous rocks, and occasionally in metallic veins.

## 6. Granular and compact.

## a. MARBLE. b. LIMESTONE.

Haüy, 1.359. Phil. 152. Haid. 2.83. Leon. 316.

Occurs massive, the masses sometimes forming considerable mountains.

Those varieties which are capable of receiving a fine polish are commonly termed *Marble*, the purest and most crystalline of which are employed in statuary. The Pentelic, found near Athens, and the Carrara from the Gulf of Genoa, are the most esteemed.

The less pure varieties, which are generally less crystalline in their appearance, and more compact in their structure, although they differ much from each other in colour and composition, pass under the common name of *Limestone*, and are applied to many well-known economical purposes. Some of the common limestones contain a considerable proportion of siliceous, alumina, and other earths. The *Calp* in Ireland, the *Aberthaw* and the *Lias* in this Country, and the *Septaria*, or Nodules, as they are termed, found in the London clay, and of which the Roman cement is made, are impure



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limestones. The impurity, however, rendering them more valuable as cements.

The fracture of the granular varieties is uneven and splintery, that of the more compact is even and flat conchoidal. Hardness and Sp.gr. rather below that of calcareous spar. Translucent to opaque. Lustre variable. Of almost all colours. Streak white or slightly coloured.

Found abundantly in every part of the World.

7. *Earthy.*a. CHALK. *Agaric Mineral. Rock Milk.*

Haüy, 1.362. Phil. 158. 150. Haid. 2.83. Leon. 321.

Chalk occurs in beds of very considerable extent.

Fracture earthy. Soft. Sp.gr. about 2.3. Opaque.

Dull. Colour white, sometimes yellowish or greyish. Is meagre to the touch.

*Agaric Mineral* is a spongy carbonate of lime, the particles of which are less coherent than those of chalk, with which it agrees in colour and most of its other characters.

*Rock Milk* is an absurd name for a variety of carbonate of lime, which occurs in the form of a fine white powder in the crevices of calcareous rocks.

Found in several parts of England, and in other Countries.

8. *Globular Concretions*a. *ISOLITE. Peustone.*

Haüy, 1.369. Phil. 158. Haid. 2.83. Leon. 319.

Occurs massive, consisting of globules from one eighth to half an inch in diameter, imbedded in a calcareous cement. Opaque. Colour brownish, reddish, yellowish-white. Streak white.

Found at Carlsbad, and a few other places.

b. *OOLITE. Roestone.*

Haüy, 1.360. Phil. 157. Haid. 2.83. Leon. 318.

Occurs massive, in beds of considerable extent, formed of small globules of different sizes, seldom as large as one-eighth, of an inch in diameter, cemented together by calcareous matter. Opaque Dull Colour greyish, brownish, yellowish white. Streak white.

The Bath stone affords a good example of this substance.

9. *Incrusting. Sedimentary.*a. *TUFA. Travertino.*

Haüy, 1.370. Phil. 160. Haid. 2.63. Leon. 320.

The most impure and irregular of all the varieties of carbonate of lime, varying considerably in the cohesion of its particles, from a nearly pulverulent state (some Tufas) to that of a compact building stone. (Travertino.) It is a concrete production of many springs and streams in this and other Countries, and may be observed in abundance at Matlock in Derbyshire, near Cambridge, near Ventnor in the Isle of Wight, and in some other places.

It is found incrusting grass and moss at the edges of the water, and stons, leaves, and other substances immersed in it. Small baskets and birds' nests coated with this deposit, are sold as objects of curiosity.

*Prismatic Carbonate of Lime*, No. 442.

a. *ARRAGONITE. The coralloidal variety, Flos-ferri.*

Haüy, 1.432. Phil. 161. Haid. 2.79. Leon. 324.

Occurs in attached and imbedded, simple and compound crystals, frequently acicular, and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.

$M, M' = 116^\circ 10'$ . Cleavage parallel to the lateral planes. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 2.9. Transparent, translucent. Lustre vitreous. Colour white, grey, reddish-brown. Streak greyish-white.

*Massive varieties.* Globular, reniform, coralloidal, and amorphous. Structure fibrous, either parallel or diverging, and sometimes, although rarely, compact.

Found in several places in England, Scotland, and Ireland, and in many other Countries. The best crystals occur at Arragon, in Spain, whence the name, at Leogang in Salzburg, and near Bilin in Bohemia. And very perfect masses of the branched variety (flos-ferri) at Dufton, and in the Quantock hills in Somersetshire.

b. *SATIN SPAR?*

Phil. 150. Haid. 2.83. Leon. 315.

Occurs in tabular masses of one or two inches thick, in veins in slaty clay or shale. Structure fibrous, the fibres parallel, generally waved, and always transverse to the direction of the vein. Harder than calcareous spar. Sp.gr. 2.7. Translucent. Lustre silky. Colour white, sometimes yellowish or greyish.

Found at Alston Moor in England, in Scotland, and in North America.

*Carbonate of Magnesia and Lime.*

1. *Crystallized.*a. *The surfaces flat, or nearly so.*

*BITTERSAR. Micemite. Tharandite.* No. 447.

Haüy, 1.427. Phil. 162. Haid. 2.94. Leon. 305.

Occurs in attached and imbedded crystals, and amorphous masses.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 106^\circ 15'$ . Cleavage parallel to the primary planes. distinct. Fracture conchoidal. Hard. 3.5, 4.0. Sp.gr. 2.884. Transparent, translucent. Lustre vitreous, occasionally pearly. Colour white, gray, black, brown, yellow, green, of different shades. Streak greyish-white.

Found in the Tyrol in talc, in Piedmont, at Miemo in Tuscany, and in some other places. But there are few localities in which good crystals are produced.

b. *The planes curved.*

*PEARLSAR. Brown Spar* (in part.)

Haüy, 1.421. Phil. 165. Haid. 2.94. Leon. 305.

Occurs in attached and generally aggregated crystals with curved surfaces.

Primary form a Rhomboid. Cryst. fig. 106. Probably of the same angles as bitterspar, but from the curvature of the planes they cannot be measured. Translucent. Lustre pearly. Colour white, sometimes greyish, brownish, or yellowish.

Found in many parts of Europe and America.

2. *Granular.*a. *DOLomite. Magnesian Limestone. Conite.* Leon. 305.

Occurs in mountain masses. Structure sometimes slaty. Fracture irregular. Softer than common limestone. Translucent, opaque. Colour white, sometimes greyish or yellowish.

The Apennines are partly composed of *Dolomite*, and the *magnesian limestone* is found in an extensive bed lying between Nottingham and Sunderland. It also occurs in other parts of the World. Some of the varieties are flexible when split or cut into

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thin slabs. *Conite* is found only in Iceland. Is described as having a fracture imperfectly conchoidal, and is said to scratch glass, whence it is probable that it does not belong to this species. Sp.gr. 3.0. Opaque. Dull. Colour flesh-red.

## 3. Compact.

## a. GURHOFFIAN.

Phil. 106. Haid. 2.94. Leon. 308.

Occurs massive. Amorphous. Structure compact. Fracture flat conchoidal. Opaque. Dull. Colour white, sometimes yellowish. Streak white.

Found near Gurhoff, in Lower Austria.

*Carbonate of Magnesia, Lime and Iron*, No. 449.

P.M. and An. 2.231.

## a. Occurs crystallized in rhomboids. Sp.gr. 2.927.

Colour yellowish white.

Found at Tenzen in the Grisons.

E.J.S. 2.179.

## b. Occurs in crystalline masses, cleavable into rhomboidal laminae. Sp.gr. 2.64. Opaque. Colour brown.

Found at Montiers in Savoy.

## c. Crystalline masses. Sp.gr. 2.9. Colour violet-blue.

Found at Notre-Dame-du-Pré in Savoy, and is supposed to contain free oxide of iron.

No angles given of either of these varieties, the chemical elements of which differ in their proportions.

*Carbonate of Lime and Iron*.

a. ANKERITE. *Rohwand. Wandstein* of Stiria. No. 444.

Haid. 2.100. Leon. 308.

Primary form a Rhomboid. Cryst. fig. 106.

$P, P' = 106^\circ 12'$ . Cleavage parallel to the primary planes. Fracture uneven. Lustre vitreous, inclining to pearly. Hard. 3.5, 4.0. Sp.gr. 3.080. Translucent. Colour white, with tints of grey, brown, red, yellow. Streak white.

Found in Salzburg resting on beds of mica slate, and all along the chain of the Alps, resting on carbonate of iron.

The planes are generally curved, and the measured angle is probably not correct.

## b. MENTINE SPAR? No. 445.

E.J.S. 8.181.

Analysis not given, but supposed to contain lime, magnesia, oxides of iron and manganese. Primary form a Rhomboid. Cryst. fig. 107.  $P, P' = 107^\circ 14'$ . *Bréil*. Cleavage parallel to the primary planes. Hard. 3.0. Sp.gr. 3.34. 3.37. Transparent, translucent. Lustre vitreous. Colour dark greyish and yellowish-white. Streak white.

Found in small crystals in quartz at Traversella in Piedmont.

*Carbonate of Lime and Lead*.

## a. PLUMBOCALCITE, No. 445.

E.J.S. N.S. 6.79.

Occurs in attached crystals and crystalline masses.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 105^\circ 5'$ . Cleavage parallel to the primary planes, distinct. Hard. under 3.0. Sp.gr. 2.924. Transparent, translucent. Lustre vitreous, sometimes pearly. Colour white. Streak white.

Found at Wanlockhead, Lanarkshire, Scotland, among the rubbish of some old workings.

*Fluate of Lime*.

a. FLUOR. *Fluor Spar*, No. 506.

Haid. 1.505. Phil. 168. Haid. 2.69. Leon. 576.

Occurs in attached and imbedded crystals and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the regular octahedron, distinct, but seldom with perfect surfaces. Fracture conchoidal. Hard. 4.0. Sp.gr. 3.14. Transparent, translucent. Lustre vitreous. Colour white, grey, black, brown, red, yellow, green, blue, purple. Streak white or slightly coloured.

*Massive varieties*, nodular: amorphous. Structure of the nodular variety large fibrous, or columnar, the fibres divergent. Structure of the amorphous, crystalline, granular, earthy, compact, and occasionally straight or curved laminar.

Crystallized Fluor is found abundantly in England, and in some other parts of Europe. In America it occurs less frequently. The nodular variety is found only in Derbyshire; the granular and earthy in England, Norway, and some parts of Germany; and the compact in Cornwall, the Hartz, and a few other places.

## b. FLUO-ARSENATE OF LIME, No. 507.

An. 6.151.

Occurs as a yellowish crust or coating on quartz or felspar, accompanying the oxide of tin, at Finbo, near Fahlun, in Sweden.

*Native Lime*.

## a. NATIVE LIME, No. 117.

Br.M. pl. No. 1.

Occurs amorphous. Structure earthy. Easily rubbed to a powder. Opaque. Dull. Colour white.

Found near Bath.

*Nitrate of Lime*.

## a. NITRATE OF LIME, No. 519.

Phil. 177. Leon. 248.

Occurs in fibrous efflorescences, or as a fine powder, on the surface of old walls, caverns, and some calcareous rocks. The fibres are often aggregated into silky-looking tufts. Very deliquescent. Taste bitter.

*Phosphate of Lime*.

a. APATITE. *Asparagus Stone. Morozite. Phosphorite. Terre de Marmarosch*, No. 485.

Haid. 1.487. Phil. 167. Haid. 2.73. Leon. 282.

Occurs in attached and imbedded crystals and crystalline masses, massive and earthy.

Primary form a Rhomboid.  $P, P' = 88^\circ 41'$ . Haid. Cleavage parallel to the planes of a regular hexagonal prism. Fracture conchoidal. Hard. 5.0. Sp.gr. 3.18, 3.22. Transparent, translucent. Lustre vitreous, sometimes inclining to resinous. Colour white, grey, brown, reddish, yellow, green, blue, violet. Streak white.

Found in Cumberland, Cornwall, in Saxony, Bohemia, and many other parts of Europe and America.

*Massive varieties*, globular; nodular; reniform; amorphous. Structure fibrous, granular, compact. Found at Schlackenwald in Bohemia, and in Estremadura in Spain.

*Earthy variety*, greyish or greenish-white.

Found near Marmarosch in Hungary.

*Scheelite of Lime*.

a. TUNGSTEN. *Tungstate of Lime*, No. 413.

Haid. 4.372. Phil. 256. Haid. 2.113. Leon. 346.

Occurs in attached and imbedded crystals and massive.

Primary form a Square prism. Cryst. fig. 61. Cleavage parallel to *Mod. a* and *c*, fig. 62 and 64. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 5.5,

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6.076. Translucent. Lustre vitreous. Colour white, sometimes greyish and yellowish, and greyish and reddish-brown. Streak white.

Found in Cornwall and Cumberland in England, in Bohemia, Sweden, and other places in Europe, and in America.

*Silicate of Lime.*

a. WOLLASTONITE. *Tabular Spar*, No. 161.

Hauy, 2.438. Phil. 23. Haid. 2.286. Leon. 524. P.M. and An. 10.190.

Occurs in attached and imbedded crystals, and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P.M = 104^\circ 48'$ .  $M.M' = 95^\circ 38'$ . Cleavage parallel to the terminal plane and horizontal diagonal. Fracture uneven. Hard. 4.0, 5.0. Sp.gr. 2.8, 2.86. Transparent, translucent. Lustre vitreous, in some varieties pearly on the cleavage surfaces. Colour white, sometimes greyish, brownish, reddish, yellowish, greenish. Streak white.

Massive varieties, amorphous, composed of small columnar crystals lying in all directions, or fibrous, the fibres parallel or divergent.

Found in very perfect crystals at Vesuvius. Its other localities are Capo di Bove near Rome, the Banat, Lake George in North America, and a few other places.

b. OKENITE, No. 162.

E.J.S. n.s. 3.27.

Occurs in fibrous masses, having a radiated structure. Hard. 4.0, 5.0. Sp.gr. 2.28. Colour white.

Found in amygdaloid, at Disco Island, Greenland.

*Sulphate of Lime*, No. 532.

a. Crystallized.

SELENITE. *Gypsum*.

b. Massive.

ALABASTER. *Gypsum*.

Hauy, 1.527. Phil. 174. Haid. 2.57. Leon. 122.

Occurs in attached and imbedded crystals, and massive.

Primary form an Oblique rhombic prism.  $P.M = 111^\circ 34'$ ;  $M.M' = 138^\circ 38'$ ; Levy. Cleavage parallel to the oblique diagonals, very distinct, and parallel to the primary planes, indistinct. Fracture indistinct. Hard. 1.5, 2.0. Sp.gr. 2.310, 2.5. Transparent, translucent. Lustre vitreous, on cleavage planes pearly. Colour white, occasionally grey, reddish, yellow, blue. Streak white.

Massive varieties, globular and nodular, structure granular. Amorphous, structure granular, earthy, compact, fibrous, scaly, the scales slightly coherent.

Found in very many parts of Europe and America, and probably in other parts of the World. It is abundant in imbedded crystals at Shotover in Oxfordshire, and has occurred in very perfect crystals at Bex in Switzerland.

When calcined and reduced to powder, it is Plaster of Paris. It enters into the composition of some kinds of porcelain and glass. Is employed in agriculture as a manure, and forms the paste of crayons for drawing. The compact varieties are employed in sculpture.

*Anhydrous Sulphate of Lime.*

a. ANHYDRITE. *Muriacite*, *Pierre de Trippes*, *Vulpinite*, No. 533.

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Hauy, 1.562. Phil. 172. Haid. 2.62. Leon. 267. Mineralogy  
Occurs in attached crystals, rarely well formed, and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M.M' = 100^\circ 8'$ . Cleavage parallel to the lateral planes, indistinct; to the terminal planes and their two diagonals very distinct. Fracture uneven. Hard. 3.0, 3.5. Sp.gr. 2.5, 3.0. Transparent, translucent. Lustre vitreous, pearly on the cleavage surfaces. Colour white, grey, pale red, blue, violet. Streak greyish-white.

Massive varieties, nodular, contorted, amorphous. Structure granular, compact, fibrous.

Found at Halle in the Tyrol, at Bex in Switzerland, and in several other parts of Europe.

*Titanate of Lime*, &c.

a. PYROCHLOR, No. 395.

E.J.S. 6.358.

Occurs in imbedded octahedral crystals.

Primary form a Cube. Cryst. fig. 56. Fracture uneven. Hard. 5.0. Sp.gr. 4.21. Translucent, opaque. Colour reddish-brown. Streak pale.

Found in Norway and Siberia.

## MAGNESIA.

*Borate of Magnesia.*

a. BORACITE, No. 425.

Hauy, 2.56. Phil. 181. Haid. 2.347. Leon. 287.

Occurs in imbedded crystals.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the octahedron, very indistinct. Fracture uneven, imperfectly conchoidal. Hard. 7.0. Sp.gr. 2.97. Transparent, translucent. Lustre vitreous. Colour greyish, yellowish, and greenish-white. Streak white.

Found only at Segeberg in Holstein, and Lüneburg in Brunswick.

*Carbonate of Magnesia.*

a. MAGNESITE, No. 466.

Phil. 179. Haid. 3.121. Leon. 302.

Occurs in acicular crystals, massive, and in powder. Colour generally white, occasionally greyish and yellowish.

The massive varieties are found in nodular and stactitic forms and amorphous. Fracture, hardness, and specific gravity variable, according as the Mineral is more or less compact or earthy.

Found in several parts of Europe, in India, and abundantly at Hoboken in North America.

*Carbonate of Magnesia and Iron.*

a. BREUNNERIT, No. 450.

Phil. 378. Haid. 2.99. Leon. 309.

Occurs in imbedded crystals.

Primary form a Rhomboid. Cryst. fig. 106.  $P.P' = 107^\circ 30'$ . Cleavage parallel to the primary planes, very distinct. Fracture conchoidal. Hard. 4.0, 4.5. Sp.gr. 3.0, 3.2. Transparent, translucent. Lustre vitreous. Colour yellow, of different shades, and black. Streak white.

Found at Zillerthal and other places in Salzburg, and in the Tyrol.

*Hydrate of Magnesia.*

a. SHEPARDITE, No. 141.

Phil. 95. Haid. 3.112. Leon. 244.

Occurs rarely in attached or imbedded hexagonal prisms, generally in laminar masses and fibrous.

Primary form a Rhomboid. Cryst. fig. 106.  $P.P'$ ,

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unknown. Hard. 1.0, 1.5. Sp.gr. 2.33, 2.63.

Transparent, translucent. Lustre pearly. Colour white, greenish-white. Streak white.

The fibrous variety is the *Nemalite* of Nuttall.

Found at Hoboken in New Jersey, North America, and in the Isle of Unst, Shetland.

*Phosphate of Magnesia.*

a. WAGNERIT, No. 486.

Haid. 3.169. Leon. 277. P.M. and An. 1.133.

Occurs in attached or imbedded crystals.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 109^\circ 20'$ .  $M, M' = 95^\circ 25'$ . Cleavage indistinct, parallel to the horizontal diagonal. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 3.01. Transparent, translucent. Lustre vitreous. Colour greyish and reddish-yellow. Streak white.

Found at Hollgraben in Salzburg, and is said to have occurred in the United States.

*Silicate of Magnesia.*

a. MARMOLITE, No. 167.

Haid. 3.124. Leon. 762.

Occurs massive; structure columnar, irregularly intersecting. The columnar portions are foliated, having a cleavage in two directions intersecting each other. Hard. 3.5. Sp.gr. 2.47. Translucent. Opaque. Lustre pearly. Colour pale yellowish and greyish-green.

Found at Hoboken in New Jersey, North America.

It is probable that the serpentines are also silicates of magnesia, and for the present we include them in this class

b. SERPENTINE, No. 163.

Phil. 97. Haid. 3.151. Leon. 777

Occurs in imbedded crystals and massive. Fracture conchoidal, uneven, splintery. Hard. 3.0. Sp.gr. 2.2, 2.6. Nearly opaque. Lustre resinous, dull. Colour dull greenish-yellow, and various shades of green, sometimes very dark and spotted with red. Streak white, shining.

Found in all parts of the World in beds and mountain masses.

The *Steatoid* of Möller, E.J.S. n.s. 3.31, occurs in crystals at Snarum in Norway, and is said to be a variety of serpentine.

c. STEATITE. Soap Stone. Speckstein. Talc Steatite, No. 164.

Haüy, 2.493. Phil. 118. Haid. 3.157. Leon. 188, 223.

Occurs in amorphous masses, sometimes containing imbedded crystals of the same substance, of the forms of quartz and carbonate of lime. Structure compact. Fracture uneven, splintery. Soft. Sp.gr. 2.6, 2.63. Opaque. Dull. Colour yellowish and greyish-white. Streak shining. Feels greasy.

Said to be found in many parts of the World, but it is probable that several distinct Minerals, merely on account of their soapy or greasy feel, have been so named.

d. MEERSCHAUM, No. 165

Phil. 180. Leon. 222.

Occurs in imbedded masses. Structure earthy. Fracture uneven. Opaque. Dull. Colour white, sometimes slightly yellowish or greyish. Streak white.

Found in Greece, the Crimea, and some other parts of Europe.

*Sulphate of Magnesia.*

a. EPSOMITE. Epsom Salt, No. 535.

Haüy, 2.51. Phil. 180. Haid. 2.48. Leon. 116.

Occurs botryoidal, reniform, massive, as a crust on the surface of other bodies, and in solution in Mineral waters. Structure fibrous, sometimes earthy. Fracture, when observable, conchoidal. Hard. of artificial crystals 2.0, 2.5. Sp.gr. 1.75. Transparent, translucent. Lustre vitreous. Colour white. Streak white.

Found on the surface of decomposing schist, in coal pits, on old walls, and in other situations.

*Sulphate of Magnesia and Soda.*

a. BLOEDITE, No. 537.

Haid. 3.79. Leon. 125.

Occurs in fibrous masses, accompanying the Polyhalite at Ischel in Upper Austria. Fracture uneven. Translucent. Lustre nearly vitreous. Colour red.

## MANGANESE.

( ARSENIURET OF MANGANESE? No. 39.

Inst. J. 1829, 2.351.

Occurs on foliated galena. Structure fine granular. Fracture uneven. Brittle. Sp.gr. 5.55. Opaque. Lustre metallic. Colour whitish-grey, but becoming dull and covered with a fine blackish powder after exposure to the air.

Supposed to have been found in Saxony.

*Carbonate of Manganese.*

a. KÖHLERITE, No. 451.

Phil. 246. Haid. 2.106. Leon. 299.

Occurs in attached crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P'$  about  $107^\circ$ . Cleavage parallel to the primary planes. Fracture uneven. Hard. 3.5. Sp.gr. 3.59. Translucent. Lustre vitreous, or cleavage surfaces rather pearly. Colour rose-red, sometimes brownish. Streak white.*Massive varieties*, globular, botryoidal. Structure fibrous, compact. Amorphous, structure granular, fibrous, compact.

Found at Kapnic and Nagyak in Transylvania, and in Saxony, the Hartz, and other places.

*Oxide of Manganese.*

a. MANGANITE, No. 148.

E.J.S. 4.41.

Occurs in attached and imbedded crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 99^\circ 30'$ . Cleavage parallel to the lateral planes and both diagonals. Fracture uneven. Hard. 4.0, 4.25. Sp.gr. 4.32. Opaque. Lustre imperfect metallic. Colour dark brownish or greyish-black. Streak reddish-brown.*Massive varieties*, amorphous. Structure crystalline granular, large fibrous.

Found at Ilfeld in the Hartz, and in other places.

b. VARVICITE, No. 119.

P.M. and An. 5.209.

Occurs massive, and resembles Manganite in colour, but is much softer, and soils the fingers more. Sp.gr. 4.819.

Found in Warwickshire.

c. PYROLUSITE, No. 120.

E.J.S. 9.304.

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Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M'$  about  $93^\circ 40'$ . Levy. Cleavage parallel to the lateral planes and short diagonal, indistinct. Hard. 2.0, 2.5. Sp.gr. 4.82, 4.94. Opaque. Lustre metallic. Colour iron-black. Streak black.

*Massive varieties*, reniform, botryoidal, amorphous. Structure fibrous, granular.

Found in Thuringia and many other places in Europe, and in Brazil, but never at Ilfeld, with the Manganite.

d. PSILOMELANE, No. 121.

E.J.S. 4.47.

Occurs in reniform, botryoidal, and fruticose shapes, and amorphous. Structure indistinctly fibrous and granular, compact. Fracture conchoidal, even. Hard. 5.0, 6.0. Sp.gr. 4.145. Opaque. Lustre imperfect metallic. Colour bluish and greyish-black. Streak brownish-black.

Found in most depositories of manganese ores.

e. HAUSMANNITE, No. 122.

E.J.S. 4.46.

Occurs in attached octahedral crystals, and massive. Primary form a Square prism. Cryst. fig. 61.  $c, c'$ , fig. 61, =  $105^\circ 25'$ . Cleavage parallel to P.C, and  $a$ , fig. 62. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 4.722. Opaque. Lustre imperfect metallic. Colour brownish-black.

Found at Ilmenau in Thuringia.

f. BRAUNITE, No. 123.

E.J.S. 4.48.

Occurs in attached and imbedded crystals and massive. Primary form a Square prism. Cryst. fig. 64.  $c, c'$ , fig. 67, =  $109^\circ 53'$ . Cleavage parallel to  $c$ , distinct. Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 4.818. Opaque. Lustre imperfect metallic. Colour dark brownish-black. Streak the same.

Found at Elgersburg and at Wunsiedel, and perhaps in Thuringia.

*Oxide of Manganese, Iron, and Copper.*

a. BLACK COPPER. Black Oxide of Copper, No. 132.

Leon. 564.

Occurs in amorphous masses. Structure earthy. Soft, friable. Opaque. Dull. Colour black.

Found in most copper mines.

*Oxide of Manganese and Copper.*

a. CUPREOUS MANGANESE, No. 133.

Haid. 3.92. Leon 755.

Occurs reniform, botryoidal, and amorphous. Structure compact. Fracture imperfect conchoidal.

Sp.gr. 3.197, 3.216. Opaque. Lustre resinous. Colour bluish-black. Streak the same.

Found in Bohemia and ? in Chili.

*Phosphate of Manganese and Iron.*

a. ULLMANNITE, No. 490.

Phil. 248. Haid. 3.136. Leon. 284.

Occurs massive. Cleavage in three directions perpendicular to each other. Fracture flat conchoidal. Hard. 5.0, 5.5. Sp.gr. 3.44, 3.77. Opaque. Lustre resinous. Colour reddish or brownish-black. Streak yellowish-grey.

Found near Limoges in France, and ? near Pennsylvania, North America.

b. HETEROZITE, No. 491.

E.J.S. n.s. 3.359.

Occurs in scaly masses. Cleavage in three directions, giving an Oblique rhombic prism of about  $100^\circ$ .

Hard. about 5. Sp.gr. 3.524. Lustre resinous. Colour greenish or bluish-grey.

Found near Limoges.

c. HURAULITE, No. 492.

E.J.S. n.s. 3.359.

*Bi-silicate of Manganese.*

a. STRÖMITTE, No. 169.

Occurs in minute crystals. Hard. about 4.0. Sp.gr. 2.27. Transparent. Lustre vitreous. Colour reddish-yellow.

Found near Limoges.

Phil. 245. Haid. 3.122. Leon. 520.

Occurs massive. Structure crystalline. Cleavage parallel to the lateral planes of a prism of about  $92^\circ 30'$ , and to both its diagonals. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 3.54. Slightly translucent. Colour red.

Found in Sweden, and at Franklin in New Jersey, North America.

Compounds of silica, oxide of manganese, and carbonate of manganese have been indistinctly described under the names of Allagite, Rhodonite, Photzite, and Hornmangan, but whether they are distinct species may perhaps be questioned. Specimens have appeared in this Country under these names, but little resembling in their characters the published descriptions.

*Sulphuret of Manganese.*

a. KOBELLITE, No. 70.

Haüy, 4.268. Phil. 246. Haid. 3.31. Leon. 656.

Primary form a Cube. Cryst. fig. 51. Cleavage parallel to P, distinct. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 4.014. Opaque. Lustre imperfect metallic. Colour, when first fractured, dark steel-grey, but becomes greyish-black by exposure to the air. Streak dark green.

*Massive varieties*, amorphous, structure granular, compact.

Found at Nagyag in Transylvania, and ? in Cornwall.

MELLILITE, No. 361.

Haüy, 4.504. Phil. 208. Haid. 3.125. Leon. 213, 760.

Occurs in attached crystals.

Primary form a Square prism. Cryst. fig. 65. Translucent, opaque. Colour reddish and greyish-yellow, and brownish-red.

Found at Tivoli and Capo di Boye near Rome.

MERCURY.

*Chloride of Mercury.*

BAUMERITE. Horn Mercury. Muriate of Mercury, No. 68.

Haüy, 3.331. Phil. 359. Haid. 2.156. Leon. 580.

Occurs in attached crystals, and in tubercular crusts. Primary form a Square prism. Cryst. fig. 65.

Cleavage parallel to the lateral planes. Fracture conchoidal. Hard. 1.0, 2.0. Sp.gr. 6.482. Translucent. Lustre adamantine. Colour yellowish or pale grey. Streak white.

Found with other ores of Mercury in Bohemia, the Palatinate, Spain, and principally at Moschelandsberg, in Deuxpouts.

*Native Mercury.*

a. MERCURY, No. 12.

Haüy, 3.297. Phil. 357. Haid. 2.432. Leon. 696.

Fluid. Occurs in small cavities or crevices of the rock in which it is found, and is frequently accom-

## Mineralogy

panied by red silver. Sp.gr. 13.6. Opaque. Lustre bright metallic. Colour tin-white. Its principal localities are Idria in Carniola, and Almaden in Spain.

## b. NATIVE AMALGAM, No. 13.

Hauy, 3.297. Phil. 357. Haid. 2.431. Leon. 698. Occurs in attached and imbedded crystals, and massive. Primary form a Cube. Cryst. fig. 56. Cleavage flat conchoidal, very indistinct. Hard. 3.0 3.5. Sp.gr. 13.755. Opaque. Lustre bright metallic. Colour silver white. Streak the same.

*Massive variety*, amorphous. Structure compact. It is sometimes rendered semi-fluid by mixture with fluid mercury.

Found in Hungary, the Palatinate, Deuxponts, and in France, Spain, and Sweden.

*Sulphuret of Mercury.*a. CINNABAR. *Hepatic Cinnabar. Liverore*, No. 92.

Hauy, 2.313. Phil. 358. Haid. 3.44. Leon. 631. Occurs in attached crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106.  $P.P' = 71^\circ 48'$ . Cleavage distinct, parallel to plane *c*, fig. 111. Fracture conchoidal. Hard. 2.0, 2.5. Sp.gr. 8.1. Transparent, translucent. Lustre adamantine. Colour bright red, and darker shades to reddish-grey. Streak scarlet.

*Massive varieties*, amorphous. Structure granular to compact, sometimes fibrous and pulverulent.

The *Hepatic* and *Bituminous Cinnabar* appear to be mixtures of this ore with shale and coarse coal.

Found in Europe, chiefly at Idria in Carniola, at Almaden in Spain, and in the Palatinate, and in several parts of Mexico and South America.

## MESOLE, No. 209.

Haid. 3.126. Leon. 206.

Occurs in globular and reniform masses, sometimes imbedded, but generally covering a thin stratum of Mesoline. Structure fibrous, foliated, radiating. Hard. 3.5. Sp.gr. 2.37. Translucent. Lustre pearly. Colour white, sometimes yellowish.

Found in the Faroe Islands.

MESOTYPE. *Natrolite*, No. 207.

Hauy, 3.179. Phil. 123. Haid. 2.236. Leon. 204. Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M.M' = 91^\circ 10'$ . Cleavage parallel to the lateral planes. Fracture conchoidal. Hard. 5.0, 5.5. Sp.gr. 2.249. Transparent, translucent. Lustre vitreous. Colour white, with shades of grey, red, and yellow. Streak white.

*Massive varieties*, globular and reniform. Structure fibrous, radiating. Surface drusy.

Found in Iceland, the Faroe Islands, Scotland, Ireland, and in many other places, lining cavities in basaltic and porphyritic rocks and ancient lavas.

MESOLITE. *Needle Stone*, No. 208.

Corresponds nearly with the preceding description, but the angle of the prism is  $91^\circ 20'$ .

## MICA.

It is certain that several distinct species of Minerals are included under this name, merely because they may be easily split into very thin, shining plates, but they cannot at present be distinguished by any characters which have been hitherto given. The following description of crystalline forms applies principally to the micas from Vesuvius.

a. *Rhomboidal*, No. 258.

Hauy, 3.111. Phil. 106. Haid. 2.198. Leon. 437. Occurs in attached hexagonal prisms, and massive.

Primary form a Rhomboid. Cryst. fig. 106. Cleavage very distinct, perpendicular to the axis. Fracture not observable. Hardness of the cleavage surfaces 2.0, 2.5, that of the edges being 4.5, 5.5. Sp.gr. 2.7, 3.0. Transparent, translucent. Lustre vitreous, pearly on the cleavage surfaces. Colour white, grey, black, brown, pale red, dull yellow, green. Streak white, grey.

*Massive varieties*, globular, structure fibrous, foliated. Amorphous, structure foliated, granular, fibrous.

Found in primitive rocks in all parts of the World, and abundantly in the masses ejected from Vesuvius.

b. *Oblique prismatic*, No. 259.

The preceding references and descriptions will probably apply to this variety, with the exception of the crystalline form, which is an Oblique rhombic prism. Cryst. fig. 83.  $P.M = 98^\circ 40'$ .  $M.M' = 120^\circ$ . Phil.

c. *LEPIDOLITE. Lilac Mica*, No. 260.

Hauy, 3.116. Phil. 141. Haid. 2.202. Leon. 451. Occurs in amorphous masses, composed generally of small, thin, flexible scales. Fracture uneven. Sp.gr. 2.832. The scales or plates are translucent. Colour pearl-grey, rose and purple-red, and greenish. Found at Rozena in Moravia, at Utö in Sweden, in North America, and some few other places.

d. MARGARITE. *Pearl Mica*, No. 261.

Phil. 208. Haid. 2.204. Leon. 766. Occurs in thin, hexagonal, attached crystals, and in masses of small, thin, shining laminae.

Primary form a Rhomboid. Cryst. fig. 56. Cleavage distinct, perpendicular to the axis. Fracture not observable. Hard. 3.5, 4.5. Sp.gr. 3.032. Translucent. Lustre pearly, bright. Colour greyish, reddish, and yellowish-white. Streak white.

Found at Sterzing in the Tyrol.

e. RUBELLAN. *Red Mica?* No. 262.

Leon. 774. Occurs in small, imbedded, hexagonal, micaceous plates, not elastic. Soft. Sp.gr. 2.5, 2.7. Colour reddish-brown.

f. ODERIT. *Black Mica?* No. 263.

Occurs in masses which may be split into thin leaves like mica. It is opaque and black, with very little lustre, and is probably mica, containing some foreign matter, which has altered its usual appearance.

Found in Sweden.

## MOLYBDENUM.

*Sulphuret of Molybdenum.*

## a. MOLYBDENITE, No. 107.

Hauy, 4.326. Phil. 248. Haid. 3.18. Leon. 667. Occurs in imbedded hexagonal crystals, and massive. Primary form a Rhomboid. Cleavage very distinct, perpendicular to the axis. Fracture not observable. Hard. 1.0, 1.5. Sp.gr. 4.5, 4.7. Opaque. Lustre metallic. Colour lead-grey. Streak the same. Thin laminae very flexible.

*Massive variety*, amorphous, structure granular, foliated.

Found in Saxony and Bohemia, and in other places in Europe and America.

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**Mineralogy** OXIDE OF MOLYBDENUM, No. 416.

Phil. 249.

Occurs as a crust on the sulphuret, and in thin layers between its laminæ. Structure earthy, and very thin fibrous. Friable. Dull. Colour pale yellow. Found in Norway, Scotland, and North America. Has not been analyzed.

**MONTICELLITE, No. 362.**

P.M. and An. 10.265.

- A Mineral from Vesuvius, nearly resembling Peridot in its form and measurements, but requiring further examination of better specimens for the purpose of a more exact description.

**MURCHISONITE, No. 363.**

P.M. and An. 1.448.

Occurs in imbedded crystals and crystalline masses.

Primary form an Oblique rhombic prism. Cryst. fig. 83. P, h, fig. 91 =  $106^{\circ} 50'$ . Cleavage distinct parallel to P and to both its diagonals. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 2.509. Translucent, opaque. Lustre vitreous, pearly on the plane h. Colour white, with a slight tinge of red.

Found imbedded in the new red sandstone at Dawlish, and at Heavitree, near Exeter, Devonshire.

The inclination of P on h agrees very nearly, if not exactly, with the measurement on corresponding planes of the moon-stone of Ceylon, the peculiar lustre of which is observable, as in Murchisonite, only on the plane h.

**MURIATIC ACID GAS, Chlorine, No. 58.**

Occurs in the state of gas. Transparent. Sp.gr. 1.274. Odour pungent. Taste acid.

Found in the neighbourhood of active volcanoes.

**MICRONITE, No. 364.**

Appears from its cleavage, hardness, and some other characters to be felspar.

**NEPHELINE, Sommitte, No. 239.**

Haid., 3.347. Phil. 125. Haid. 2.250. Leon. 468.

Occurs in attached hexagonal prisms. Primary form a Rhomboid. Cryst. fig. 106. P, P' =  $88^{\circ} 55'$ . Haid. Cleavage *indistinct*, parallel to the planes of the hexagonal prism. Fracture conchoidal. Hard. 6.0. Sp.gr. 2.56. Transparent, translucent. Lustre vitreous. Colour white. Streak white.

Found among the matter ejected from Vesuvius.

**NICKEL.****ARSENATE OF NICKEL, No. 474.**

Haid., 3.421. Phil. 284. Haid. 2.448. Leon. 164.

Occurs as a powdery crust on the surface of arseniuret of nickel, and massive. Opaque. Dull. Colour green, and greenish-white.

Found accompanying arseniuret of nickel, and produced from the decomposition of that substance.

*Arseniuret of Nickel***COPPER NICKEL, No. 28.**

Haid., 3.417. Phil. 283. Haid. 2.446. Leon. 678.

Occurs in botryoidal and reniform masses, with a fibrous structure, more commonly amorphous. Structure compact. Fracture uneven. Splintery. Hard. 5.0, 5.5. Sp.gr. 7.65. Opaque. Lustre metallic. Colour yellowish and greyish-red of different shades. Streak pale brownish-black.

Found in Cornwall, Scotland, Saxony, Bohemia, and other parts of Europe; and in South America.

**OXIDE OF NICKEL, No. 130.**

Phil. 284.

Occurs in a green Mineral named Pimelite, but whether combined with silica, or merely colouring hydrous quartz, appears uncertain.

Found in Serpentine in Silesia.

*Sulphuret of Nickel.***NATIVE NICKEL. Capillary Nickel, No. 76.**

Haid., 3.412. Phil. 282. Haid. 3.129. Leon. 651.

Occurs in regular hexagonal capillary crystals.

Primary form a Rhomboid. Cryst. fig. 106. Opaque.

Lustre metallic. Colour yellow, sometimes greyish.

Found in Wales and Cornwall in England, and in Saxony, Bohemia, and the Hartz.

*Sulpho-arseniuret of Nickel.***NICKELGLANZ. Grey Nickel, No. 115.**

An. 15.147. Leon. 652

Occurs massive. Structure granular. Fracture of the mass uneven, the separate grains foliated. Easily frangible. Sp.gr. 6.129. Opaque. Lustre metallic. Colour pale lead-grey, becoming reddish by tarnish.

Found in Sweden and in the Hartz.

**NUTTALLITE, No. 365.**

Haid. 3.133. Leon. 765.

Occurs in attached and imbedded crystals.

Primary form a Square prism. Cryst. fig. 65, of the same dimensions as Scapolite. Cleavage parallel to the lateral planes. Fracture uneven. Hard.

4.0, 4.5. Translucent. Lustre vitreous. Colour grey.

Found at Bolton in Massachusetts. And probably some of the dark grey Scapolites from Finland will be found to belong to this species.

**OBSIDIAN. Marckanite, No. 249.**

Haid., 3.101. Phil. 112. Haid. 2.337. Leon. 413.

Occurs massive and in rolled grains. Structure compact. Fracture conchoidal. Hard. 6.0, 7.0. Sp.gr. 2.35, 2.40. Transparent, opaque. Lustre vitreous. Colour greyish-brown, greenish or brownish-black, black, dull red, and dull green.

Found in the neighbourhood of most volcanoes, and in beds and veins traversing rocks in many parts of Europe, Asia, and America.

Obsidian, Pitchstone, Pearlstone, and Pumice have been considered as belonging to the same Mineral species, from the apparent passage of one into the other, and the consequent absence of exact characters by which they may be distinguished. There appears, however, a chemical difference in their composition; the Pitchstone and Pearlstone containing water, which the others do not; on which account they have been kept separate in this Treatise.

**OSMELITE, No. 366.**

P.M. and An. 3.71.

Is said to consist of thin prismatic concretions, either scopiformly or stellately arranged, and these again collected into masses of coarse, granular concretions. Cleavage apparent in only one direction. Hard. 4.0, 5.0. Sp.gr. about 2.8. Translucent. Colour whitish, yellowish, and brownish-grey. Feels greasy. Odour strong clayey. Taste like clay, and seems to dissolve in the mouth, but without producing any apparent change in the substance.

Found at Niederkirchen, near Wolfstein, on the Rhine.

**OSMIUM**, a metal found combined with Iridium, in small

**Mineralogy**



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grains among the platina in South America and Russia. See IRIDIUM.

**OSTRANITE**, No. 367.

E.N.P.J. 4.186. Leon. 765.

Is said to occur crystallized in the form of a Right rhombic prism, of about  $96^\circ$ . Hard. about 6.5. Sp.gr. 4.32. Lustre vitreous. Colour dark brown.

Found in Norway, and supposed by M. Bréithaupt to be a new metallic oxide.

**PALLADIUM**, No. 14.

Hafy, 3.230. Phil. 325. Haid. 3.134. Leon.

Occurs in rolled grains accompanying the native platina of Brazil, and in minute particles, imbedded in and combined with much of the native gold of Brazil.

Structure of the rolled grains fibrous, divergent. Sp.gr. 11.8. Opaque. Lustre metallic. Colour whitish steel-grey.

**PEARLSTONE**, No. 245.

Phil. 112. Haid. 2.337. Leon. 182.

Occurs massive. Structure granular, the grains varying in size, and formed of thin concentric laminae. Fracture uneven. Hard. 4.5, 5.0. Sp.gr. 2.34. Translucent, opaque. Lustre pearly. Colour grey, greyish-black, blackish or reddish-brown.

Found principally at Tokay, in Hungary, also at Cabo da Gato, in Spain, and in a few other places. See OBSIDIAN.

**PEKTOLITE**, No. 225.

E.J.S. 9.364.

Occurs in spheroidal masses. Structure fibrous, radiating. Hard. 4.5, 5.5. Sp.gr. 2.69. Nearly opaque. Lustre pearly. Colour greyish-white.

Found on Natrolite at Monte Baldo, South Tyrol.

**PERIDOT**, *Chrysolite*, *Olivine*? *Hyalosiderite*? No. 283.

Hafy, 2.465. Phil. 95. 96. Haid. 2.345. Leon. 530. Occurs in attached, imbedded, and loose crystals, and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 120^\circ$ . Levy. Fracture conchoidal. Hard. 6.5, 7.0. Sp.gr. 3.441. Transparent, translucent. Lustre vitreous. Colour green of various shades, sometimes yellowish or brownish. Streak white.

*Massive varieties*, amorphous. Composition granular, the grains slightly coherent.

The locality of the Chrysolite used in jewellery is not known, but is supposed to be Upper Egypt. Olivine occurs in basalt and lava in Bohemia, Hungary, on the banks of the Rhine, and in other places.

**PETALITE**, No. 229.

Hafy, 3.137. Phil. 143. Haid. 2.248. Leon. 416.

Occurs in masses composed of smaller crystalline masses, promiscuously aggregated, sometimes so minute as to appear compact. Cleavage parallel to the lateral planes and both diagonals of a rhombic prism of about  $100^\circ$ . Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 2.44. Translucent. Lustre vitreous. Colour white. Streak white.

Found at Ulf in Sweden, and in North America.

**PICROLITE**, No. 251.

Phil. 209. Haid. 3.136. Leon. 225.

Occurs massive. Structure thin fibrous, Fracture splintery. Hard. 3.0, 6.0. Nearly opaque. Little lustre, inclining to pearly. Colour yellowish-green.

Found at Taberg and Nordmarken in Sweden.

**PICROSIMINE**, No. 252.

Haid. 3.137. Leon. 512, 768.

Occurs crystallized and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 117^\circ 49'$ . Cleavage distinct parallel to P, indistinct parallel to the long diagonal and to M. Fracture indistinct, uneven. Hard. 2.5, 3.0. Sp.gr. 2.66. Nearly opaque. Lustre dull vitreous, pearly on the surface M. Colour greenish-white, green of several shades, sometimes blackish. Streak white.

*Massive varieties*: structure thin fibrous, fracture splintery; granular to compact, fracture earthy.

Found at Engelsburg in Bohemia.

**PINITE**, No. 266.

Hafy, 2.353. Phil. 80. Haid. 3.139. Leon. 464.

Occurs in imbedded crystals, which are generally hexagonal prisms.

Primary form a Rhomboïd. Cryst. fig. 106. P, P' unknown. Cleavage very indistinct. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 2.78, 2.98. Opaque. Lustre slightly resinous. Colour greenish-grey, blackish-brown, brown, blackish-green.

Found in Saxony, Auvergne, England, and some other parts of Europe, and in North America.

**PINGUITE**, No. 368.

E.N.P.J. 9.382. Leon. 468.

Occurs massive at Beschert-Gluck, Saxony, and is said to resemble Bole and Green iron earth; two names under which several substances differing in most of their characters appear to have been classed. Hence they afford little indication of the characters of Pinguite.

**PITCHSTONE**, No. 246.

Phil. 130. Haid. 2.337. Leon. 151.

Occurs massive. Structure compact, sometimes slaty. Fracture imperfect conchoidal, one of the characters by which it is distinguished from Obsidian. Hard. 5.0, 6.0. Sp.gr. 2.3, 2.7. Translucent, opaque. Lustre resino-vitreous. Colour grey, black, brown, red, yellow, green, blue, dull and sometimes variously mixed.

Found at Meissner in Saxony, in Ireland, the Western Islands of Scotland, and in other places.

See OBSIDIAN.

**PLATINA**, No. 15.

Hafy, 3.226. Phil. 324. Haid. 2.441. Leon. 705.

Occurs in grains of various sizes. No cleavage. Fracture hackly. Hard. 4.0, 4.5. Sp.gr. 17.332. Opaque. Lustre metallic. Colour steel-grey. Streak shining.

Found in Peru, Brazil, and lately in Russia.

**PLURANIUM**, P.M. and An. 2.391, 5.234.

A metal said to have been discovered in the Russian Platina by Professor Osann of Dorpat.

**POLYHALLITE**, No. 538.

Phil. 199. Haid. 3.141. Leon. 769. E.J.S. 7.246.

Occurs crystallized and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' =$  about  $115^\circ$ . Cleavage indistinct, parallel to  $M, M'$ . Fracture uneven. Hard. 2.5. Sp.gr. 2.73, 2.77. Opaque. Lustre resinous. Colour pale flesh-red, sometimes yellowish.

Found at Ischel in Upper Austria.

**POONAHLITE**, No. 369.

P.M. and An. 10.109.

Occurs in long slender crystals accompanying Apophyllite and Stilbite.

Mineralogy

## Mineralogy

Primary form a Right rhombic prism. *Cryst.* fig. 71.  $M, M' = 92^\circ 20'$ . Fracture uneven. Transparent, translucent. Lustre vitreous. Colourless, white.

Found at Poonah in the East Indies.

## POTASH.

## Nitrate of Potash.

a. NITRE. *Saitpetre*, No. 517.

Haüy, 2.177. Phil. 189. Haid. 2.34. Leon. 247. Occurs in crusts and capillary fibres, on or near the surface of the earth, and in old walls, &c. Hard. 2.0. Sp.gr. 1.93. Transparent, translucent. Lustre of the fractured surface vitreous. Colour white, sometimes yellowish. Taste saline and cool.

Found in most parts of the World.

## Sulphate of Potash.

a. BERNHARDITE, No. 524.

Haüy, 2.187. Haid. 3.159. Leon. 271.

Occurs at Mount Vesuvius in small white tubercular or globular masses on lava. Hard. 2.5, 3.0. Sp.gr. 1.737. Translucent, Lustre of the fractured surface vitreous.

PREHNITE, No. 222.

*Koupholite* when in very thin crystals.

Haüy, 2.603. Phil. 36. Haid. 2.217. Leon. 470. Occurs in attached and aggregated crystals and massive.

Primary form a Right rhombic prism, *Cryst.* fig. 71.  $M, M' = 99^\circ 50'$ . Cleavage distinct, parallel to P, less so parallel to the lateral planes. Fracture uneven. Hard. 6.0, 7.0. Sp.gr. 2.926. Transparent, translucent. Lustre vitreous. Colour white, grey, yellow, green of various shades. Streak white.

*Massive varieties*, globular, botryoidal, nodular, stactitic. Structure broad fibrous. Amorphous, structure granular, compact. Surfaces rough, drusy.

Found originally at the Cape of Good Hope, and since at many places in Europe, America, and Asia.

PUMICE, No. 247.

Phil. 133. Haid. 2.337. Leon. 411.

Occurs massive. Structure fibrous, and very porous. From its porous structure it floats on water. Translucent, opaque. Lustre of some varieties vitreous, but generally pearly. Colour grey, sometimes brownish or yellowish.

Found principally in the Lipari Islands.

See OBSIDIAN.

PYRALLOLITE, No. 166.

Phil. 68. Haid. 3.141. Leon. 512.

Occurs crystallized and massive. Cleavage parallel to the lateral planes of a prism of about  $94^\circ 36'$ . Fracture earthy. Hard. 3.5, 4.0. Sp.gr. 2.55, 2.60. Translucent, opaque. Lustre resinous. Colour white, occasionally greenish or yellowish.

*Massive variety*, structure fibrous, granular.

Found at Pargas in Finland.

PYRARGILLITE, No. 370.

Occurs in bluish and brownish-black amorphous masses, in a felspar or granitic rock in Finland.

PROPHYLLITE, No. 255.

Formerly known as *Radiated Talc*, but newly named *Mineralogy* on account of its ready exfoliation on exposure to heat.

PYROSOMALITE, No. 282.

Phil. 235. Haid. 3.143. Leon. 772.

Occurs in attached and imbedded hexagonal prisms.

Primary form a Rhomboid. *Cryst.* fig. 106. Cleavage distinct perpendicular to the axis, indistinct parallel to the planes of the prism. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 3.08. Transparent, opaque. Lustre of the transparent variety, vitreous, of the opaque, pearly on the cleavage surface. Colour greyish-green. Streak pale.

Found at Nordmark in Sweden.

PYROXENE. *Alalite*. *Baikalite*. *Diopside*. *Fassait*. *Malacolite*. *Mussite*. *Pyrgum*. *Sahlite*. No. 268 to 272.

Haüy, 2.407. Phil. 58. Haid. 2.268. Leon. 503.

Occurs in attached and imbedded crystals and massive.

Primary form an Oblique rhombic prism. *Cryst.* fig. 83.  $P, M = 105^\circ 45'$ .  $M, M' = 87^\circ 5'$ . Cleavage parallel to the lateral planes and to both the diagonals. Fracture conchoidal, uneven. Hard. 5.0, 6.0. Sp.gr. 3.23, 3.35. Transparent to opaque. Lustre vitreous, vitreo-resinous. Colour white, grey, black, brown, yellow, green, of many shades. Streak purer colour.

*Massive varieties*, amorphous. Structure granular, columnar, parallel, and radiating; laminar.

Found in most basaltic rocks, in lava, and in the older rocks in most parts of the World.

RADIOLITE? No. 224.

E.J.S. 10.370.

The notice referred to is that of an analysis by Hunefeld of a substance called Radiolite, unaccompanied by any description or indication of locality. A specimen in the writer's possession, so named we believe by Esnark, exactly resembles the fibrous Mineral from Norway named *Bergmannite*. But whether this is the Mineral analyzed by Hunefeld is uncertain.

RAZOUKOFFSKIN, No. 371.

An. 4.215. 7.62.

A white powder discovered by Lentz in the clefts of quartz rocks in Silesia. In vol. iv. of the *Annals of Phil.* it is said to be composed of *silica*, *alumina*, *potash* and *water*; and in vol. vii. it is said to contain *silica*, *magnesia*, and *carbonic acid*. Hence two different Minerals have passed under this name.

RHODIUM. A brittle metal found by Dr. Wollaston in combination with native platinum as an alloy.

RHUTENIUM. P.M. and An. 2.391. 5.233.

A metal said to have been discovered in the Russian platinum by Professor Osann of Dorpat.

SAPHIRINE, No. 313.

Leon. 775.

Occurs in thin crystalline plates, separated by plates of mica. Fracture uneven. Hard. 7.0, 8.0. Sp.gr. 3.42. Translucent. Lustre vitreous. Colour blue, sometimes greenish. Streak white.

Found in Greenland.

SARCOLITE, No. 372.

P.M. and An. 10.189.

Occurs in attached crystals.

Primary form a Square prism. *Cryst.* fig. 61. Trans-

## Mineralogy

parent, translucent. Lustre vitreous. Colour white, and pale flesh-red.

Found in cavities in the masses ejected from Vesuvius. Red *Analcime* and *Gmelinite* have incorrectly passed under this name merely on account of their colour.

SCAPOLITE. *Paranthine*. *Wernerite*. *Chelmsfordite*, No. 285.

Haüy, 2.586. Phil. 137. Haid. 2.264. Leon. 474. Occurs in attached and imbedded crystals and massive.

Primary form a Square prism. Cryst. fig. 61. Frequently decomposed and dull on the surface. Cleavage parallel to the primary planes and both the diagonals. Fracture uneven. Hard. 5.0, 5.5. Sp.gr. 2.72. Translucent, opaque. Lustre vitreous. Colour white, grey, green, red.

Found in Norway, Sweden, Finland, Greenland, and in North America.

*Meionite*, No. 236. Generally in transparent crystals from Vesuvius.

## SCHEELIUM.

a. OXIDE OF SCHEELIUM. *Scherlic Acid?* *Tungstic Acid?* No. 412.

Phil. 254.

Occurs massive, with some appearance of crystalline form. Fracture conchoidal. Sp.gr. 6.0. Translucent. Lustre adamantine. Colour yellow of different shades, sometimes greyish. Resembles sulphur in appearance. Inodorous. Tasteless. Insoluble in acids.

Found in quartz in a mine near Baltimore? North America.

SCHILLER SPAR. *Diallage Metalloide*. No. 287.

Haüy, 2.455. Phil. 71. Haid. 2.206. Leon. 517.

Occurs in crystalline plates and small aggregated crystals generally in serpentine. Cleavage parallel to the lateral planes and to both the diagonals of a rhombic prism of about  $93^{\circ} 30'$ . The angle of  $135^{\circ}$  to  $140^{\circ}$  quoted by Haidinger is evidently the inclination of a *primary* to a *diagonal* plane, which is  $136^{\circ} 15'$ . Fracture uneven, scarcely observable. Hard. 3.5, 4.0. Sp.gr. 2.69. Nearly opaque. Lustre pearly metallic. Colour yellowish and blackish green.

Found at Baste in the Hartz, at Zöblitz in Saxony, and a few other places.

SCHOARITE, No. 529.

Leon. 258.

This Mineral is said to be fibrous, and composed of 10 parts of silice and 90 of sulphate of barytes, and to be soluble in sulphuric acid.

Its professed locality is Carlisle, in the State of New York, North America.

SELENIUM, No. 45.

Occurs as a red coating on sulphur, and sometimes in small globular and botryoidal shapes, with a smooth and bright surface. Fracture conchoidal. Translucent. Lustre vitreous. Colour pale dull red.

Found in the Lipari Islands.

SIDEROCEPTE, No. 373.

Gal. 273.

Soft. Translucent. Lustre greasy. Colour yellowish-green.

Found in the lavas of the extinct volcanoes of Briegau.

SULPHURET OF SELENIUM, No. 110.

E.P.J. 13.190. Leon. 599.

Found in the Lipari Islands, disposed in layers, and of a brownish-yellow colour.

## SILICA.

Haüy, 2.228. Phil. 1. Haid. 2.321. Leon. 372.

The differences of structure, hardness, specific gravity, mixture with foreign matter, and other characters belonging to this species, are so numerous as to render any single description inapplicable to all its varieties. And the intimate connection of some of these with others, into which they appear to pass by insensible degrees, as that of brittle opal into tough chalcedony, renders it equally impracticable to define with precision their respective limits. It will, however, be convenient to divide the species first into *anhydrous*, which we simply term *quartz*, and *hydrous quartz*; and each of these into smaller subdivisions.

QUARTZ, No. 154.

a. The structure crystalline.

1. Attached, imbedded, and aggregated crystals.

Colourless, transparent. *Rock crystal*.

Coloured, and of various degrees of transparency and translucency.

White.

Grey.

Black.

Brown. *Smoky quartz*.

Red. *Compostella quartz*.

Yellow, transparent.

nearly opaque. *Eisen Kiesel*.

Green, transparent.

nearly opaque. *Prase*.

Blue, translucent. *Siderite*.

Purple. *Amethyst*.

Primary form a Rhomboid.  $P.P. = 94^{\circ} 15'$ . Cleavage parallel to the planes of the hexagonal prism and pyramids of the ordinary crystals. Fracture conchoidal. Hard. 7.0. Sp.gr. 2.69. Transparent to opaque. Lustre vitreous, in some varieties resinous. Colour of almost every variety.

2. Amorphous.

Colourless, transparent. *Rock crystal*.

Slightly bluish pale grey. *Milky quartz*.

Slightly greyish with little lustre. *Fat quartz*.

Pale red. *Rose quartz*.

Pale green, a variety of *Amethyst*.

Pale brownish-red, and greenish-grey, slightly coloured, penetrated by *Amianthus*. *Catsye*.

Blue. *Siderite*.

Containing minute fissures or scales of mica which reflect many brilliant points of light. *Avanturine*.

3. Massive aggregations of particles in which the crystalline structure is apparent.

Fibrous, the fibres parallel or divergent.

Granular, the grains varying in size, and cohering with different degrees of force, or being loose in the form of sand.

b. The crystalline structure of the particles not apparent.

*Chalcedony*. Botryoidal, stalactitic, reniform, nodu-

lar, amorphous, and sometimes in pseudomorphous crystals of the forms of carbonate of lime, (Hornstone,) and of Datholite. (Haytorite.) The nodular varieties are

*Onyx*, when composed of flat layers or bands of different colours.

*Agate*, when the bands are concentrically curved.

Other varieties are

*Sard*, brownish-yellow.

*Plasma*, dark green, translucent.

*Chrysoprase*, when pale green:

*Carneian*, when white, or brownish or yellowish-red.

*Heliotrope*, dark green spotted with red, opaque.

*Flint*, in nodular and tabular masses of various shades of black and grey, and of other colours.

*Mixed with variously coloured clays and other extraneous matter, and generally opaque.*

*Jasper*, principally red, yellow, brown, and green of many shades.

*Flinty slate*, *Basanite* *Touchstone* Colour dark greyish-black.

#### HYDROUS QUARTZ, No. 155.

Occurs nodular and amorphous.

OPAL distinguished as

*Precious*, when it presents iridescent

*Fire opal*, when the internal colours are bright.

*Hydrophane*, when transparent. Colours of the precious opal may be destroyed by immersion in water. *Appendix.*

*Common opal*, when the colours, which are very various, are simple.

*Semi-opal*, when it is dull and opaque.

*Wood opal*, showing the woody structure.

*Cacholong*, white opaque opal.

*Opal jasper*, if mixed with much foreign matter.

*Menilite*, opaque and brown.

*Hyalite*, *Fiorite*, in small globular and botryoidal forms.

*Geyserite*, *Silicious sinter*, No. 159. *Silicious Deposits from the hot springs in Iceland and elsewhere.*

Structure compact, resembling opal, to fine granular and earthy.

#### HYDROSILICITE, No. 156.

*Appendix to Quartz.*

P.M. N.S. 371.

Occurs in amorphous masses in serpentine. Fracture even. Soft. Translucent. Dull. Colour white.

Feels greasy.

Found at Frankenberg in Silesia, accompanying chrysoprase, opal, and pumelle.

#### KONILITE, No. 157.

Phil 207. Leon. 753.

Occurs in the form of a loose white powder in some of the amygdaloids in the Highlands of Scotland and some of the Western Islands. It appears from analysis to be nearly pure siliceous, but its ready fusibility into a transparent colourless bead induced Dr. Macculloch to suppose that it contained some other matter besides a small portion of lime which easily separated from it.

#### TRIPOLI, and POLISHING SLATE, No. 158.

Leon. 785.

These appear to be nearly similar compounds of silica in a finely divided state, with small proportions of alumina and oxide of iron.

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They are massive, earthy, friable, and of a greyish, brownish, or yellowish colour.

Found in France, Italy, and some parts of Germany.

#### SILVER.

##### *Stibiuret of Silver.*

##### a. ANTIMONIAL SILVER, No. 26.

Haüy, 3.258. Phil. 236. Haid. 2.427. Leon. 685. Occurs crystallized, granular, and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.

M.M' about 120°. Cleavage parallel to the terminal plane and short diagonal of the prism. Fracture uneven. Hard. 3.5. Sp.gr. 9.44, 9.82. Opaque. Lustre metallic. Colour silver-white. Streak the same.

*Massive varieties*, amorphous, structure granular. foliated.

Found in the Hartz, in Salzburg, and at Guadalupe in Spain.

*Arsenical Stibiuret of Silver* frequently accompanies the preceding, of which it is considered a variety containing a mixture of arsenic.

##### *Carbonate of Silver.*

##### a. SELBITE, No. 459.

Haüy, 3.290. Phil. 295. Leon. 702.

Occurs massive and disseminated in veins traversing granite. Structure fine granular. Fracture uneven. Soft. Heavy. Opaque. Lustre metallic. Colour greyish-black.

Found at Altwolfach in the Black Forest.

##### *Chloride of Silver.*

##### a. LAXMANNITE. *Horn Silver*. *Muriate of Silver*, No. 67.

Haüy, 3.292. Phil. 295. Haid. 2.154. Leon. 581. Occurs crystallized and massive.

Primary form a Cube. Cryst. fig. 56. No cleavage.

Fracture uneven. Hard 1.0, 1.5. Sp.gr. 5.55. Translucent. Lustre resinous, bright. Colour grey, yellow, green, blue of different shades, mostly dull. Streak shining. Sectile.

Found with other ores of silver in several parts of Europe and America.

##### *Iodide of Silver.*

##### a. HERRERITE, No. 57.

Nuevo Sistema Mineral, por Del Rio, p. 8.

Structure lamellar. Soft. Externally white, internally yellowish.

Found in serpentine at Albarradon in the State of Zacatecas, Mexico.

##### *Native Silver.*

##### a. SILVER, No. 11.

Haüy, 3.249. Phil. 285. Haid. 2.433. Leon. 699. Occurs crystallized, dendritic, capillary, and massive.

Primary form a Cube. Cryst. fig. 56. No cleavage.

Fracture hackly. Hard. 2.5. 3.9. Sp.gr. 10.473. Opaque. Lustre metallic. Colour white. Streak shining.

*Massive varieties*, amorphous, laminar.

Found in many different places in Europe and America.

b. *Auriferous Native Silver* does not appear to form a distinct chemical species, but differs in the proportions of gold and silver in different specimens.

##### *Seleniuret of Silver and Copper.*

##### a. EUCAIRITE, No. 54.

Mineralogy

**Haüy, 3.470. Phil. 294. Haid. 3.94. Leon. 593.**  
Occurs in small granular masses in a serpentine rock.  
Soft. Opaque. Lustre metallic. Colour greyish-white.

Found in Sweden.

*Sulphuret of Silver.*

**2. HENKELITE. Silver Glance, No. 88.**

**Haüy, 3.265. Phil. 288. Haid. 3.11. Leon. 635.**  
Occurs in attached and aggregated crystals and massive.

Primary form a Cube. Cryst. fig. 65. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 7.196. Opaque. Lustre metallic. Colour lead grey, sometimes blackish from tarnish.

*Massive varieties*, amorphous, laminar.

Found in most silver mines.

*Sulphuret of Silver and Iron?*

**a. SPERNBERGITE, No. 91. Flexible Sulphuret of Silver of Bournon. Cat 209.**

**E.J.S. 7.242. Leon. 779.**

Occurs in attached crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 119^\circ 30'$ . Cleavage distinct parallel to the terminal plane. The laminae very flexible. Hard. 1.0, 1.5. Sp.gr. 4.215. Opaque. Lustre metallic. Colour dark brown, often with a blue tarnish. Streak black.

Found at Joachimsthal in Bohemia.

*Sulphuret of Silver and Antimony.*

**RED SILVER.**

*Rhomboidal.*

**a. BRAARDITE, No. 104**

**Haüy, 3.269. Phil. 291. Haid. 3.38. Leon. 610.**  
Occurs in attached crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 108^\circ 30'$ . Cleavage parallel to the primary planes, generally indistinct. Fracture conchoidal. Hard. 2.0, 2.5. Sp.gr. 5.846. Translucent. Opaque. Lustre adamantine. Colour red, of different shades, frequently dark and blackish. Streak red.

*Massive varieties*, amorphous, structure granular, compact.

Found in many parts of Europe and America.

*Oblique Prismatic.*

**b. MARGYRITE, No. 105.**

**Haid. 3.42.**

Occurs in attached crystals.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $M, M' = 86^\circ 4'$ .  $P, h$ , fig. 91,  $101^\circ 6'$ . Cleavage imperfect. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 5.234. Nearly opaque. Lustre bright metallic. Colour iron-black. Streak dark red.

Found near Freiberg in Saxony.

*Right Prismatic.*

**c. POLYBASITE. Brittle Silver, No. 106.**

**Haüy, 3.230. Phil. 390. Haid. 3.27. Leon. 638.**  
Occurs in attached and aggregated crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 111^\circ 8'$ . Haid. Cleavage imperfect. Fracture uneven. Hard. 2.0, 2.5. Sp.gr. 6.269. Translucent. Opaque. Lustre metallic. Colour iron-black.

Found in Saxony, Bohemia, and other parts of Europe, and in Mexico and Peru.

Among the numerous specimens named Brittle Silver

in the Mineral collections in this Country, we have not observed one agreeing in crystalline form with the above description.

*Sulphuret of Silver and Antimony.*

**a. ROMELITE. Mine d'Argent grise Antimoniale, No. 103**

**De l'Isle, 3.54. Phil. 290. Haid. 3.30. Leon. 685.**

Occurs in attached crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 100^\circ$ . Phil. Cleavage parallel to the lateral planes. Sp.gr. 5.5. Opaque. Lustre metallic. Colour nearly silver-white.

Found near Freiberg.

*Sulphuret of Silver and Copper.*

**a. SILVERKUPFERGLANZ, No. 89.**

**Phil. 293. Haid. 3.73. Kirwan, 2.121.**

Occurs massive. Compact. Fracture flat conchoidal. Soft. Sp.gr. 6.255. Opaque. Lustre metallic. Colour dark lead-grey. Streak shining.

Found in Siberia.

*Sulphuret of Silver, Lead, and Bismuth.*

**a. BISMUTHIC SILVER, No. 90.**

**Phil. 294. Haid. 3.78. Leon. 618.**

Occurs in acicular crystals and massive.

Fracture uneven. Opaque. Colour when first broken light lead-grey, but liable to tarnish.

*Massive varieties*, amorphous, structure compact.

Found at Shapbach in Baden, in a bed of gneiss.

*Sulpho-telluret of Silver and Bismuth.*

**a. MOLYBDIC SILVER. Molybden Silver, No. 21.**

**Phil. 287. Haid. 3.127. Leon. 589.**

Occurs in small laminated masses at Deutsch Pilsen near Grard, and resembles the Sulpho-telluret of Bismuth, but is said to be composed of sulphur, bismuth, tellurium, and silver. It appears, however, to be an uncertain species.

**SODA.**

*Borate of Soda.*

**a. BORAX. Tincal, No. 424.**

**Haüy, 2.200. Phil. 192. Haid. 2.52. Leon. 148.**  
Occurs in single crystals and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 101^\circ 30'$ .  $M, M' = 86^\circ 40'$ . Cleavage parallel to the lateral planes and both diagonals. Fracture conchoidal. Hard. 2.0, 2.5. Sp.gr. 1.716. Transparent, translucent. Lustre resinous. Colour slightly greyish, greenish, or bluish-white. Streak white.

Found chiefly in a lake in Thibet, and also in Persia and in South America.

*Carbonate of Soda.*

**a. Oblique Rhombic, No. 432.**

**Haüy, 2.207. Phil. 190. Haid. 2.27. Leon. 149.**  
Occurs crystallized, massive, and in powder.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 108^\circ 45'$ .  $M, M' = 76^\circ 12'$ . Levy. Cleavage parallel to the primary planes and oblique diagonal. Fracture conchoidal. Hard. 1.0, 1.5. Sp.gr. 1.423. Transparent, translucent. Lustre vitreous. Colour white, sometimes yellowish or greyish. Streak white. Very efflorescent.

*Massive varieties*, structure fibrous, granular.

Found abundantly in Hungary and the natron lakes of Egypt, and in some other places.

Mineralogy

Mineralogy *b. Right Rhombic, No. 433.*

Haid. 229.

Occurs in crystals lining cavities of the massive varieties of the preceding species.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 107^\circ 50'$ . Cleavage indistinct. Fracture conchoidal. Hard. 1.5. Sp.gr. 1.562. Transparent, translucent. Lustre vitreous. Colour white, sometimes yellowish. Streak white. Less efflorescent than the preceding species.

*c. TRONA, No. 434.*

Phil. 190. Haid. 231. Leon. 149.

Occurs in crystalline coats, with a fibrous structure.

Primary form an Oblique rhombic prism. Cryst. fig. 83. Measurements uncertain. Cleavage parallel to P, distinct. Fracture uneven. Hard. 2.5. 3.0. Sp.gr. 2.112. Transparent, translucent. Lustre vitreous. Colour white, sometimes yellowish. Streak white. Does not effloresce.

Found on the banks of lakes in the Kingdom of Fezzan in Africa.

*d. Bicarbonate of Soda? No. 435.*

N.J. 35. 48.

Occurs in strata of two to six inches thick on a bed of clay containing muriate of soda. Structure granular. Colour yellowish-grey, does not effloresce.

Found near Buenos Ayres.

*Carbonate of Soda and Lime.*

*a. GAY LUSSITE, No. 436.*

E.J.S. 5.372. P.M. and An. 1.263.

Occurs in imbedded crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 68^\circ 50'$ . Cleavage parallel to the lateral planes distinct; less so parallel to the terminal plane. Fracture conchoidal. Hard. 2.5. Sp.gr. 1.93, 1.99. Transparent. Lustre vitreous. Colourless.

Found in a thin stratum of soft clay covering a bed of carbonate of soda, called *Urao*, at the bottom of a lake near Lagunilla, a day's journey South-West of Merida in Columbia.

*b. BARRUELITE, No. 437.*

P.M. and An. 7.389.

Occurs in crystalline masses. Cleavage distinct, parallel to the planes of a rhomboid, supposed to be similar to that of carbonate of lime. Hard. 3.5. Sp.gr. 2.921. Transparent. Lustre vitreous. Colour not described.

Locality unknown.

Differs from Gay Lussite in the proportions of its constituent elements. But the accuracy of the analysis appears to be questioned by Berzelius.

*Chloride of Sodium.*

*ROCK SALT, No. 59.*

Haid. 236. Phil. 193. Haid. 236. Leon. 584.

Occurs in solution in water, and massive. Structure crystalline, fibrous.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the primary planes. Fracture conchoidal. Hard. 2.0. Sp.gr. 2.257. Transparent, translucent. Lustre vitreous, rather dull. Colour white, grey, red, yellow, blue. Streak white. Taste saline.

Found abundantly in Europe, Asia, Africa, and America. The great salt deposits in this Country are Northwich in Cheshire, and Droitwich in Worcestershire.

*Nitrate of Soda.*

*a. RIVEROLITE, No. 518.*

Haid. 2.214. Phil. 191. Haid. 3.132. Leon. 246.

Occurs with clay in beds of different thickness.

Primary form a Rhomboid. Cryst. fig. 106.  $P, P' = 106^\circ 33'$ . Haid. Cleavage parallel to the primary planes. Fracture conchoidal. Hard. 1.5, 2.0. Sp.gr. 2.096. Transparent. Lustre vitreous. Colour white. Streak white. Taste cool.

Found crystallized in the district of Atacama in Peru.

*Sulphate of Soda.*

*a. GLAUBER SALT, No. 525.*

Haid. 2.189. Phil. 191. Haid. 2.31. Leon. 125.

Occurs in solution in water, and as an efflorescence on soil and other surfaces.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 101^\circ 20'$ .  $M, M' = 80^\circ 24'$ . Cleavage parallel to the terminal planes. Fracture conchoidal. Hard. 1.5, 2.0. Sp.gr. 1.48. Transparent, translucent. Lustre vitreous. Colour white. Streak white. Taste cool, bitter.

Found in several places in and out of Europe.

*Anhydrous Sulphate of Soda.*

*a. THENARDITE, No. 526.*

E.J.S. 6.182. An. N.S. 12.313.

Occurs crystallized.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M'$  about  $125^\circ$ . Cleavage parallel to the primary planes. Sp.gr. about 2.73. Translucent, opaque. Soluble in water.

Found at Espertines near Madrid.

*Sulphate of Soda and Lime.*

*a. GLAUBERITE. Brongmartin, No. 534.*

Haid. 2.215. Phil. 198. Haid. 2.54. Leon. 270.

Occurs in imbedded crystals in rock salt.

Primary form an Oblique rhombic prism. Cryst. fig. 83.  $P, M = 101^\circ 15'$ .  $M, M' = 83^\circ 20'$ . Cleavage parallel to P and M. Fracture conchoidal. Hard. 2.5, 3.0. Sp.gr. 2.807. Transparent, translucent, but becomes opaque after immersion in water. Lustre vitreous. Colour yellowish and greyish-white. Streak white. Taste slightly saline.

Found at Oaia in New Castle, and at Aussee in Upper Austria.

*Sulphate of Soda and Magnesia.*

*a. REUSSITE, No. 536.*

A salt said to consist of about two-thirds sulphate of soda, and one-third sulphate of magnesia, but of which we do not find any published description.

*SODALITE, No. 240.*

Haid. 3.59. Phil. 127. Haid. 2.226. Leon. 461.

Occurs in attached and aggregated crystals and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the Rhombic dodecahedron. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 2.3. Translucent. Lustre vitreous. Colour greenish-grey and greenish and greyish-white. Streak white.

Massive varieties, amorphous. Structure granular, compact. Minerals from Greenland, Siberia, and Vesuvius have passed under this name, but it is doubtful whether they all belong to the same species.

*SOMERVILLITE. Humboldtite of Manticelli, No. 374.*

## Mineralogy

**Q.J. 16.274.** Haid. 3.154. Leon. 484.  
Occurs in attached crystals.  
Primary form a Square prism. Cryst. fig. 65.  $P_a = 147^\circ 5'$ . Cleavage perpendicular to the axis, very distinct. Fracture uneven. Transparent, translucent. Lustre vitreous. Colour dull pale brownish-yellow.  
Found in the cavities of matter ejected from Vesuvius.

**SORDAWALITE, No. 309.**  
Phil. 210. Haid. 3.155. Leon. 799.  
Occurs massive. Structure compact. Fracture conchoidal. Hard. 5.0. Sp.gr. 2.53. Opaque. Lustre vitreo-metallic. Colour greenish or greyish-black.  
Found near Sordawala in Finland.

**SPHERULITE, No. 248.**  
Phil. 209. Haid. 3.155. Leon. 780.  
Occurs in small spheroidal and botryoidal masses imbedded in pearly and pitchstone. Structure fibrous, compact. Hard. 7.0, 7.5. Sp.gr. 2.4, 2.52. Opaque. Dull. Colour grey, brown, red, yellow of various shades.  
Found in Hungary, Saxony, Iceland, and Scotland.

**SPINELLANE, No. 566.**  
Haüy, 4.507. Phil. 127. Haid. 3.156. Leon. 459.  
Occurs in imbedded dodecahedral crystals in a rock of glassy felspar.  
Primary form a Cube. Cryst. fig. 56. Cleavage distinct, parallel to the planes of the Rhombic dodecahedron. Fracture uneven. Hard. 5.5, 6.0. Sp.gr. 2.28. Translucent, opaque. Lustre vitreo-resinous. Colour grey, greyish-black, brown.  
Found at the Lake of Loach. This might have been called Sodalite with as much propriety as the variety from Vesuvius.

**SPINELLE. Pionaste. Candile. Balas Ruby, No. 147.**  
Haüy, 2.166. Phil. 90. Haid. 2.295. Leon. 544.  
Occurs in loose and imbedded octahedral crystals.  
Primary form a Cube. Cryst. fig. 56. Cleavage indistinct. Fracture conchoidal. Hard. 8.0. Sp.gr. 3.5, 3.7. Transparent, translucent. Lustre vitreous. Colour black, brown, red, yellow, green, blue, violet. Streak white.  
Found in loose crystals in Ceylon, and imbedded in carbonate of lime in Sweden and North America.

**SPODUMENE. Traphane, No. 230.**  
Haüy, 3.134. Phil. 142. Haid. 2.216. Leon. 433.  
Occurs in imbedded crystalline masses of various sizes.  
Cleavage parallel to the lateral planes and great diagonal of a Rhombic prism of about  $93^\circ$ . Fracture uneven. Hard. 6.5, 7.0. Sp.gr. 3.17, 3.19. Transparent. Lustre pearly on the cleavage planes.  
Colour white, sometimes greyish and greenish, and greyish-green. Streak white.  
Found in Sweden, the Tyrol, Ireland, and in North America.

**Soda Spodumene, No. 231.**  
Lustre more vitreous than the preceding.

**STAUROLITE. Grenatite. Staurolite, No. 321.**  
Haüy, 2.338. Phil. 82. Haid. 2.366. Leon. 409.  
Occurs in imbedded crystals.  
Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 129^\circ 20'$ . Phil. Cleavage parallel to the lateral planes and both diagonals. Fracture uneven. Hard. 7.0, 7.5. Sp.gr. 3.3, 3.72. Transparent,

translucent. Lustre vitreo-resinous. Colour dark brownish-red. Streak white.

Found in France, Spain, Portugal, and some other parts of Europe, and in North America.

## STILBITE, No. 213.

Haüy, 3.155. Phil. 37. Haid. 2.239. Leon. 193.  
Occurs in attached and variously aggregated crystals.  
Primary form a Right rhombic prism.  $M, M' = 94^\circ 11'$ . Levy. Cleavage parallel to both the diagonals. Fracture uneven. Hard. 3.5, 4.0. Sp.gr. 2.16, 2.5. Transparent, translucent. Lustre vitreous. Colour white, brown; red, yellow. Streak white.

The aggregated crystals are sometimes fasciculated.  
Found abundantly in Iceland and the Faroe Islands, and generally in trap rocks.

## STRONTIA.

## Carbonate of Strontia.

## STRONTIANITE, No. 439.

Haüy, 2.43. Phil. 186. Haid. 2.116. Leon. 328.  
Occurs in acicular, rarely in tabular crystals, and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 117^\circ 30'$ . Cleavage distinct parallel to  $M, M'$ . Fracture uneven. Hard. 3.5. Sp.gr. 3.6, 3.67. Transparent, translucent. Lustre vitreous. Colour white, grey, pale, brown, and green. Streak white.

Massive varieties, globular, amorphous. Structure fibrous, with a pearly lustre, rarely granular.

Found at Strontian in Scotland, Braunsdorf in Saxony, Leogang in Salzburg, and in Peru.

## Barytiferous Carbonate of Strontia.

## STROMNITE, No. 440.

Haid. 3.159.

Occurs massive, in veins in clay slate.

Structure fibrous with traces of crystallization. Hard. 3.5. Sp.gr. 3.7. Translucent. Lustre inclining to pearly. Colour yellowish and greyish-white.

Found at Stromness in Orkney.

## Sulphate of Strontia.

## CELESTINE, No. 530.

Haüy, 2.30. Phil. 187. Haid. 2.126. Leon. 262.  
Occurs crystallized and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M, M' = 104^\circ$ . Cleavage parallel to the primary planes. Fracture uneven. Hard. 3.0, 3.5. Sp.gr. 3.6, 3.86. Transparent, translucent. Lustre vitreous, pearly on the cleavage surfaces. Colour white, pale blue, and red of different shades.

Massive varieties, nodular, tabular, amorphous. Structure columnar, fibrous, granular.

Found in Sicily, at Bex in Switzerland, at Lake Erie, North America, in the Tyrol, and some other places, and massive near Bristol.

## Sulphate of Strontia and Barytes.

## GRUNERITE. Radiated Celestine, No. 531.

E.P.J. 11.329. Leon. 266.

Occurs in beds in a coarse limestone. Structure radiated. Hard. 3.0, 3.5. Sp.gr. 3.7619. Translucent. Lustre vitreous. Colour white, occasionally with a shade of blue.

Found at Norten near Hanover.



Mineralogy

SULPHUR.

a. NATIVE SULPHUR, No. 69.

Haüy, 4.407. Phil. 360. Haid. 3.52. Leon. 595.  
Occurs in attached crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.

$M.M' = 101^\circ 59'$ . Haid. Cleavage indistinct.

Fracture conchoidal. Hard. 1.5, 2.5. Sp.gr. 2.072.

Transparent, translucent. Lustre resinous. Colour yellow, greenish-grey. Streak paler.

Massive varieties, stalactitic, of various shapes. Structure compact. Amorphous, structure crystalline, granular, compact.

Found in beds in primitive and secondary rocks in several parts of Europe, and generally in volcanic Countries. Most of the sulphur of commerce comes from Solfatara near Naples.

b. SULPHURIC ACID, No. 521.

Phil. 144. Haid. 2.23.

Occurs as a gas issuing from active volcanoes, also in a fluid state in their neighbourhood, and in a concrete form in grottos and caves in the mountain Raccolino, near Sienna, and in some other volcanic districts.

Odour of the gas pungent; taste of the fluid and solid strongly acid and burning.

TACHYLITE, No. 311.

E.N.P.J. 1.364. Leon. 781.

Occurs massive and in plates.

No cleavage. Fracture small, conchoidal. Hard. 6.5. Sp.gr. 2.50, 2.51. Translucent, opaque. Lustre vitreous, vitreo-resinous. Colour brownish and greenish-black. Streak dark grey. Resembles Obsidian.

Found at Sasabühl, near Gottingen.

TALC. Potstone, No. 254.

Haüy, 2.489. Phil. 116, 117, 120. Haid. 2.193. Leon. 444.

Occurs in attached and aggregated hexagonal crystals and massive.

Primary form a Rhomboid. Cryst. fig. 106. Cleavage distinct, perpendicular to the axis. Hard. 1.0, 1.5. Sp.gr. 2.713. Translucent. Lustre pearly. Colour white, greyish, and green of many shades. Streak the same.

Massive varieties, granular, earthy.

Found in all parts of the World.

It is probable that several distinct species of Minerals have passed under this name.

TANTALITE. Columbite, No. 402 to 408.

Haüy, 4.387. Phil. 269. Haid. 2.390. Leon. 319.

Occurs in attached and imbedded crystals and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.

$M.M' = 104^\circ$  nearly. Fracture uneven. Hard.

6.0. Sp.gr. 6.038. Opaque. Lustre imperfect metallic. Colour greyish-black.

Massive variety, nodular, amorphous. Structure granular, compact.

Found in Finland, Sweden, Bavaria, and North America.

TAUOLITE, No. 375.

E.J.S. 8.181.

Occurs crystallized in the volcanic rocks, at Lake Loach.

Primary form a Right rhombic prism. Cryst. fig. 71.

$M.M' = 109^\circ 48'$ . Cleavage parallel to M and the greater diagonal. Fracture uneven. Hard. 6.5, 7.0. Sp.gr. 3.865. Opaque. Lustre vitreous. Colour black. Streak grey.

TELLURIUM.

a. NATIVE TELLURIUM, No. 19.

Haüy, 4.372. Phil. 326. Haid. 2.424. Leon. 691.

Occurs in minute attached Hexagonal prisms and massive.

Primary form a Rhomboid. Cryst. fig. 106.

Massive variety, structure granular. Hard. 2.0, 2.5.

Sp.gr. 6.115. Opaque. Lustre metallic. Colour tin-white.

Found at Facebay in Transylvania.

b. GRAPHIC TELLURIUM. *Auro-argentiferous Tellurium*, No. 24.

Haüy, 4.380. Phil. 327. Haid. 3.21. Leon. 690.

Occurs in attached flattened crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.

$M.M' = 107^\circ 44'$ . Phil. Fracture uneven. Hard.

1.5, 2.0. Sp.gr. 5.72. Opaque. Lustre metallic.

Colour steel-grey.

Found only in Transylvania.

c. YELLOW TELLURIUM, No. 23.

Phil. 328. Haid. 3.171. Leon. 691.

Occurs in imbedded crystalline laminae. Lustre metallic. Colour silver or yellowish-white.

Found in Transylvania.

d. BLACK TELLURIUM. *Foliated Tellurium. Auro-plumbiferous Tellurium*, No. 22.

Haüy, 4.381. Phil. 328. Haid. 3.16. Leon. 689.

Occurs in attached and aggregated crystals and in imbedded foliated masses.

Primary form a Square prism. Cleaves into thin flexible laminae parallel to the terminal plane.

Hard. 1.0, 1.5. Sp.gr. 7.085. Opaque. Lustre metallic.

Colour dark lead-grey.

Found in Transylvania.

THOMSONITE, No. 212.

Phil. 39. Haid. 3.162. Leon. 208.

Occurs massive. Structure large fibrous, radiated; the fibres prolonged into separate small columnar crystals in the cavities.

Primary form a Right rhombic prism.  $M.M' = 90^\circ 40'$  nearly. Cleavage parallel to the two diagonals.

Fracture uneven. Hard. 5.0. Sp.gr. 2.37. Trans-

parent, translucent. Lustre vitreous. Colour

white.

THORITE, No. 376.

Q.J. 6.296.

Occurs massive, and much resembles the Gadolinite of Ytterby. Fracture uneven, very brittle, full of cracks. Hard. about 5.0. Sp.gr. 4.63. Opaque. Lustre resinous, vitreous. Colour black. Streak greyish-red. Powder pale brownish-red.

Found in Syenite, on the Island of Lovön, near Brevig, Norway.

TIN.

*Oxide of Tin.*

a. TINSTONE, No. 139.

Haüy, 4.152. Phil. 250. Haid. 2.984. Leon. 354.

Occurs in attached and imbedded crystals and massive.

Mineralogy

Primary form a Square prism. Cryst. fig. 65. Cleavage parallel to the lateral planes and both diagonals. Fracture uneven. Hard. 6.0, 7.0. Sp.gr. 6.960, crystallized, 6.319, fibrous. Transparent to opaque. Lustre adamantine. Colour white, grey, black, brown, red, yellow, of various shades. Streak paler.

Massive varieties, reniform, botryoidal, (Wood tin,) structure fibrous; amorphous, structure crystalline, granular.

Found abundantly in Cornwall, Bohemia, Saxony, and in the older rocks in other Countries.

Sulphuret of Tin and Copper.

#### a. TIN PYRITES, No. 87.

Phil. 254. Haid. 3.163. Leon. 624.

Occurs in attached crystals and massive.

Primary form not ascertained. Cleavage imperfect. Fracture uneven. Hard. 4.0. Sp.gr. 4.35. Opaque. Lustre metallic. Colour yellowish-grey. Streak black.

Found in Cornwall.

### TITANIUM.

#### Oxide of Titanium.

#### a. ANATASE. Octahedrite, No. 386.

Haüy, 4.344. Phil. 257. Haid. 2.379. Leon. 358. Occurs in attached and imbedded octahedral crystals.

Primary form a Square prism. Cryst. fig. 65. M.C (fig. 68) =  $155^{\circ} 24'$ . Cleavage parallel to the terminal plane, and to those of the octahedron. Fracture indistinct. Hard. 5.5, 6.0. Sp.gr. 3.826. Transparent, translucent. Lustre adamantine. Colour white, brown, blue. Streak white.

Found in Cornwall, Dauphiny, Brazil, and a few other places.

#### b. RUTILE, No. 387.

Haüy, 4.333. Phil. 258. Haid. 2.376. Leon. 360. Occurs in attached and imbedded crystals and crystalline masses.

Primary form a Square prism. Cryst. fig. 65. M.C (fig. 68) =  $122^{\circ} 45'$ . Cleavage parallel to the lateral planes. Fracture uneven. Hard. 6.0, 6.5. Sp.gr. 4.219. Transparent to opaque. Lustre adamantine. Colour red and reddish-brown of several shades. Streak pale brown.

Found in Brazil, North America, Spain, and other parts of Europe.

#### c. BROOKITE? No. 388?

An.P. 1825. Haid. 3.82. Leon. 725.

Occurs in attached crystals.

Primary form a Right rhombic prism. Cryst. fig. 71. M.M' =  $100^{\circ}$ . Levy. Cleavage parallel to the lateral planes and short diagonal. Fracture uneven. Hard. 5.5, 6.0. Transparent to opaque. Lustre adamantine. Colour deep red and reddish, and yellowish-brown. Streak yellowish-white.

Found at Snowdon in Wales, in large crystals, in Dauphiny, Switzerland, and a few other places.

Silico titanate of Lime.

#### a. SPHENE. Spunthere. Semiline, No. 394.

Haüy, 4.353. Phil. 262. Haid. 2.373. Leon. 368. Occurs in attached and imbedded crystals and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83. P.M =  $121^{\circ} 30'$ . M.M' =  $133^{\circ} 30'$ . Phil. Cleavage indistinct. Fracture uneven. Hard. 6.0, 5.5. Sp.gr. 3.468. Transparent to opaque.

Lustre adamantine to dull resinous. Colour grey, brown, yellow, green. Streak white.

Found in primitive rocks in several parts of Europe and America.

#### TOPAZ. Pycnite. Pyrophysalite, No. 516.

Haüy, 2.131. Phil. 84. Haid. 2.308. Leon. 401. Occurs in attached, loose, and imbedded crystals, and massive.

Primary form a Right rhombic prism. M.M' =  $124^{\circ} 23'$ . Cleavage parallel to the terminal plane distinct, to the lateral planes indistinct. Fracture uneven. Hard. 8.0. Sp.gr. 3.5. Transparent to nearly opaque. Lustre vitreous. Colour white, yellow of many shades, brownish-yellow, pink, blue, green. Streak white.

Massive variety, (Pycnite,) structure columnar.

Found in Brazil in loose crystals, and in primitive rocks in many other Countries, particularly in Siberia.

#### TORRELITE, No. 377.

An. N.S. 9.217. Haid. 3.164. Leon. 482. 784.

Occurs in granular masses in the Andover mine, Sussex County, New Jersey. Colour dull vermilion-red. It was at first supposed to contain cerium, but by a later analysis it appears to consist principally of silica, lime, and oxide of iron and manganese.

#### TOURMALINE. Black, Electric Schorl. Blue, Indicolite. Red to purple, Rubellite. Apryite, No. 429.

Haüy, 3.14. Phil. 139. Haid. 2.349. Leon. 446. Occurs in attached, imbedded, and aggregated crystals.

Primary form a Rhomboid. Cryst. fig. 106. P.P' =  $133^{\circ} 26'$ . Cleavage imperfect. Fracture uneven. Hard. 7.0, 7.5. Sp.gr. 3.076. Transparent to opaque. Lustre vitreous. Colour white, grey, brown, red, yellow, green, blue.

Found in Siberia, Ceylon, Brazil, North America, and many other places.

#### TURNERITE, No. 378.

Phil. 382. Haid. 3.166. Leon. 786.

Occurs in attached crystals.

Primary form an Oblique rhombic prism. Cryst. fig. 83. Cleavage parallel to both diagonals of the prism. Hard. 4.5, 5.0. Transparent, translucent. Lustre vitreous. Colour yellow, sometimes brownish.

Found at Mount Sorel in Dauphiny.

The *Pélite* of Lametherie is said by Gallitzin (1802) to be the *Sphene* of Haüy. But it is described as pointed as a graver, and nearly equal to the gems in hardness, and is probably, therefore, *Axinite*.

### URANIUM.

#### Oxide of Uranium.

#### a. PITCHBLEND. Uran-pitch-dre, No. 138.

Haüy, 4.316. Phil. 267. Haid. 2.393. Leon. 565.

Occurs in reniform and amorphous masses. Structure granular, compact. Fracture uneven. Hard. 5.5. Sp.gr. 6.468. Opaque. Lustre imperfect metallic. Colour greyish and brownish-black.

Found in Cornwall, but chiefly in Saxony and Bohemia.

#### Phosphate of Uranium.

#### a. URANITE. Uran-mica, No. 504.

Mineralogy

Haüy, 4.319. Pfl. 267. Haid. 2.182. Leon. 140. Occurs in attached crystals.

Primary form a Square prism. Cryst. fig. 65. P.c (fig. 68) =  $112^{\circ} 10'$ . Cleavage parallel to the terminal plane very distinct. Hard. 2.0, 2.5. Sp.gr. 3.1. Transparent, translucent. Lustre adamantine. Colour yellow, greenish-yellow, and green of several shades.

Found in Cornwall, France, and some parts of Germany.

The green variety has received the name of *Chalkolite*, No. 505.

*Sulphate of Uranium and Copper.*

a. JOHANNITE, No. 563.

E.J.S. n.s. 3.306. Leon. 115.

Occurs in small botryoidal concretions. Hard. 2.0, 2.5. Sp.gr. 3.191. Translucent. Lustre vitreous. Colour bright grass-green. Streak pale green. Soluble in water. Taste astringent, bitter. Found at Joachimsthal in Bohemia.

VARGASITE, No. 379.

A pale greenish Mineral found in Finland, in amorphous masses, having a small columnar structure, and so named after Count Vargas Bodemar.

No analysis or description published.

WERTHITE, No. 380.

A rolled mass found near St. Petersburg has been so named. Structure small, columnar. Colour pale yellowish white.

WIDHAMITE, No. 381.

E.J.S. 2.218. Haid. 3.170. Leon. 476

Occurs in small imbedded globular masses, composed of minute crystals, radiating from the centre, and having the form and measurements of Epidote. Hard. 6.0, 6.5 Sp.gr. 3.137. Translucent. Lustre vitreous. Colour red. Streak white.

Found at Glenape in Scotland.

WOLKONSKOIT, No. 382.

Occurs massive, amorphous, structure compact. Hard. 2.5 Sp.gr. 2.213. Opaque. Nearly dull. Colour emerald-green. Streak shining. Feels greasy.

Found at Perm in Siberia.

XANTHITE, No. 383.

Is said to be yellow Idocrase. Found in North America.

XANTHOLITE, No. 384.

Found in North America. Has the appearance and form of Garnet.

XYLOKRYPTITE, No. 589.

Occurs in delicate yellow crystals in Lignite, having a fatty lustre.

## YTTRIA.

*Phosphate of Yttria.*

a. TANKELITE, No. 487.

E.J.S. 327. Leon. 276.

Occurs in aggregated crystals and massive.

Primary form a Square prism. Cleavage parallel to the primary planes. Fracture uneven. Hard. 4.5, 5.0. Sp.gr. 4.56. Opaque. Lustre resinous. Colour yellowish-brown. Streak pale brown.

Found near Linderoës in Norway.

*Silicate of Yttria and Iron.*

a. GADOLINITE. Ytterbite, No. 325, 326.

Haüy, 2.440. Phil. 105. Haid. 2.371. Leon. 526. 500.

Occurs in imbedded crystals and massive.

Primary form an Oblique rhombic prism. Cryst. fig. 83. P.M =  $96^{\circ}$ . M.M' =  $115^{\circ}$ , nearly. No apparent cleavage. Fracture flat conchoidal. Hard. 6.5, 7.0. Sp.gr. 4.238. Slightly translucent. Lustre vitreo-resinous. Colour greenish-black. Streak greenish-grey.

Massive varieties, amorphous, structure compact.

Found at Ytterby, Finbo, and Broddbo in Sweden, and in Greenland.

*Tantalate of Yttria, &c.*

a. YTTRO-TANTALITE, No. 399 to 401.

Haüy, 4.389. Phil. 271. Haid. 3.173. Leon. 352.

Occurs in imbedded imperfect crystals, and small amorphous masses. Cleavage in one direction.

Fracture granular. Hard. 5.0, 5.5. Sp.gr. 5.4, 5.8. Opaque. Lustre vitreo-resinous. Colour black, brownish-black, yellowish-brown.

Found at Ytterby in Sweden.

*Tantalate of Yttria and Cerium.*

a. FERGUSONITE, No. 398.

Haid. 3.98. Leon. 738.

Occurs in imbedded crystals in quartz.

Primary form a Square prism. Cryst. fig. 65. Cleavage uncertain. Fracture conchoidal. Hard. 5.5, 6.0. Sp.gr. 5.538. Opaque. Lustre resinous-metallic. Colour brownish-black. Streak pale brown.

Found near Cape Farewell in Greenland.

*Titanate of Yttria, Zircon, and Lime.*

a. POLYMIGNITE, No. 396.

E.J.S. 3.329.

Occurs in imbedded crystals.

Primary form a Right rhombic prism. Cryst. fig. 71. M.M' =  $110^{\circ} 30'$  nearly. Fracture conchoidal. Hard. 6.5. Sp.gr. 4.8. Opaque. Lustre imperfect metallic. Colour black. Streak dark brown.

Found at Frederiksvæn in Norway.

ZEAGONITE. *Abrazite. Gismondine. Phillipsite.* No. 219.

Phil. 11. Haid. 3.174. Leon. 198.

Occurs in attached crystals, and globular crystalline masses with a fibrous structure.

Primary form unknown, probably a Right rhombic prism, the apparently Square prisms being twin crystals. Fracture conchoidal. Hard. 7.0, 7.5. Transparent to opaque. Lustre vitreous. Colour white, sometimes greyish or reddish. Streak white.

Found at Vesuvius, and frequently in trap rocks.

Small crystals of zircon of a pale blue colour have come to this Country ticketed Zeagonite, and have led to an incorrect description of the crystalline form of that Mineral.

## ZINC.

*Aluminate of Zinc.*

AUTOMALITE. *Gahnite*, No. 150.

Haüy, 2.170. Phil. 83. Haid. 2.298. Leon. 544.

Occurs in imbedded octahedral crystals, and granular masses.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the octahedron, distinct. Fracture conchoidal. Hard. 8.0. Sp.gr. 4.232.

Mineralogy

Mineralogy

Slightly translucent. Lustre vitreous. Colour dull green. Streak white.

Found at Fahlun and Broddbo in Sweden, imbedded in slaty talc.

*Carbonate of Zinc.*

CALAMINE, No. 454.

Haüy, 4.181. Phil. 355. Haid. 2.111. Leon. 158. Occurs crystallized and massive.

Primary form a Rhomboid. Cryst. fig. 106.  $P.P' = 107^\circ 40'$ . Wollaston. Cleavage parallel to the primary planes. Fracture uneven. Hard. 5.0. Sp.gr. 4.44. Translucent, opaque. Lustre vitreous. Colour white, grey, brown, green. Streak white.

*Massive varieties*, reniform, botryoidal, stalactitic, structure fibrous. Amorphous, structure granular, compact. Both varieties are sometimes found in an earthy state.

Found in England, France, and other places in Europe, and in America.

*Red Oxide of Zinc.*

a. SPARTALITE, No. 124.

Haüy, 4.179. Phil. 353. Haid. 2.380. Leon. 563. Occurs in imbedded small nodules and massive.

Cleavage parallel to all the planes of a regular hexagonal prism. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 5.43. Translucent. Lustre adamantine. Colour red. Streak orange-yellow.

*Massive varieties*, amorphous, structure crystalline, granular.

Found in New Jersey, North America.

*Bisulphuret of Zinc and Proto-sulphuret of Mercury. Del Rio.*

a. RIOLITE, No. 55.

Q.J. 4.232. P.M. and An. 4.113.

Occurs massive, structure granular. Sp.gr. 5.56.

Lustre metallic. Colour light grey.

Found at Culebras in Mexico.

*Bisulphuret of Zinc and Bisulphuret of Mercury. Del Rio.*

CULEBRITE, No. 56.

P.M. and An. 4.114.

Occurs massive. Fracture earthy. Sp.gr. 5.66. Dull. Colour dull red.

Found at Culebras in Mexico.

*Silicate of Zinc.*

a. SMITHSONITE. *Electric Calamine*, No. 168.

Haüy, 4.175. Phil. 254. Haid. 2.108. Leon. 216.

Occurs in attached, and globular, and botryoidal aggregations of crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M.M' = 102^\circ 35'$ . Cleavage parallel to the lateral planes. Fracture uneven. Hard. 5.0. Sp.gr. 3.38. Transparent, translucent. Lustre vitreous. Colour white, brown, yellow, greenish, and bluish. Streak white.

Found at Mallock in Derbyshire, in other parts of England, and in many other parts of Europe.

*Sulphate of Zinc.*

a. LISTERITE, No. 539.

Haüy, 4.198. Phil. 356. Haid. 2.46. Leon. 110.

Occurs crystallized and massive.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M.M' = 91^\circ 7'$ . Fracture conchoidal. Hard. 2.0, 2.5. Sp.gr. 2.036. Transparent, translucent. Lustre vitreous. Colour white, occasionally reddish or bluish. Streak white.

*Massive varieties*, botryoidal, reniform, stalactitic; structure fibrous. Amorphous, structure granular, compact. Sometimes coating other substances.

Found in most mines that contain the sulphuret, from the decomposition of which this species appears to be produced.

*Sulphuret of Zinc.*

BLENDE, No. 71.

Haüy, 4.186. Phil. 351. Haid. 3.32. Leon. 622.

Occurs in attached crystals and massive.

Primary form a Cube. Cryst. fig. 56. Cleavage parallel to the planes of the rhombic dodecahedron. Fracture conchoidal. Hard. 3.5, 4.0. Sp.gr. 4.07. Transparent to opaque. Lustre adamantine. Colour white, (New Jersey, North America,) black, brown, red, yellow, green. Streak paler.

*Massive varieties*, globular, botryoidal, reniform, stalactitic; structure fibrous. Amorphous, structure crystalline, granular, compact. A fibrous variety contains cadmium.

Found in many parts of Europe and America.

*Zinc and an Acid not yet ascertained.*

a. HOPEITE, No. 571.

Haid. 3.109. Leon. 746

Occurs in attached crystals.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M.M' = 101^\circ 24'$ . Cleavage parallel to the great diagonal, distinct. Fracture uneven. Hard 2.5, 3.0. Sp.gr. 2.76. Transparent, translucent. Lustre vitreous. Colour greyish-white. Streak white.

Found at Altenberg near Aix la Chapelle.

b. TEPHROITE? No. 570.

Leon. 752.

Occurs amorphous. Fracture uneven. Hard. 5.5. Sp.gr. 4.10. Lustre adamantine. Colour ash-grey, becoming black externally.

Found with Franklinite, &c in New Jersey, North America.

## ZIRCONIA.

*Silicate of Zirconia.*

ZIRCON. *Hyacinth. Jargoon*, No. 180.

Haüy, 2.291. Phil. 99. Haid. 2.368. Leon. 387.

Occurs in attached, imbedded, and loose crystals.

Primary form a square prism. Cryst. fig. 65.  $M,c$  (fig. 68)  $= 132^\circ 12'$ . Phil. Cleavage parallel to the lateral planes, indistinct. Fracture conchoidal. Hard. 7.5. Sp.gr. 4.5. Transparent to opaque. Lustre nearly adamantine. Colour grey, brown, red, yellow, pale green. Streak white.

Found in many parts of the World.

*Titanate of Zirconia, Cerium, &c*

ÆSCHYNITE, No. 397.

E.J.S. n.s. 3.28. P.M. and An. 10.188.

Occurs in imbedded columnar crystals in mica and felspar.

Primary form a Right rhombic prism. Cryst. fig. 71.  $M.M' = 127^\circ$ . Cleavage not apparent. Fracture uneven. Hard. 5.0, 7.0. Sp.gr. 5.14. Opaque. Lustre imperfect, metallic. Colour black. Streak greyish-black.

Found at Miask in Siberia.

ZOISITE, No. 290.

Haid. 2.282. Leon. 476.

Mineralogy

Mineralogy.

Occurs in imbedded and aggregated columnar crystals.

Primary form an Oblique rhombic prism. P,M (unknown.) M,M =  $116^{\circ} 30'$ . Fracture uneven.

Translucent. Lustre vitreous. Colour white, grey, brown, green of several shades.

Found in Carinthia, the Tyrol, Siberia, and other places.

ZURLITZ, No. 305.

Monticelli, *Prodromo de la Mineralogia Vesuviana*, p. 392. Leon. 787.

Occurs crystallized and massive.

Primary form a Cube or Square prism. Fracture uneven. Hard. 4.0, 4.5. Sp.gr. 2.274. Colour asparagus-green.

Found at Vesuvius.

Mineralogy.

## I N D E X.

THE names of those species which are placed in their alphabetical order in the preceding List are also repeated in this Index for the purpose of giving the entire series of species alphabetically. Those which are chemically arranged in the List will be found here, accompanied by references to the chemical groups in which they stand in the List.

Many synonymes, now nearly obsolete, are omitted in this Index, and it is much to be wished that the Mineralogists of different Countries could agree upon some single nomenclature, which might render a future repetition of any synonymes altogether unnecessary.

## A.

Abrazite. Zeagonite.  
Achmite.  
Actinolite. Amphibole.  
Adamantine Spar. Corundum.  
Adularia. Felspar.  
Aegonolite. Sphærolite.  
Aerolite. Native Iron.  
Aerosite. Antimonial Sulphuret of Silver.  
Æschynite. Titanate of Zirconia, &c.  
Agalmatolite. Hydrous Silicate of Alumina, *b*.  
Agapite. Calcite.  
Agate Mineral. Earthy Carbonate of Lime.  
Agate. Calcédony.  
Agnesite. Carbonate of Bismuth.  
Akanticonc. Epidote.  
Alabaster. Compact Sulphate of Lime.  
Alalite. Pyroxene.  
Albn. Apophyllite.  
Albite. Cleavelandite.  
Alagite. Manganese.  
Allanite. Silicate of Cerium and Iron.  
Allochroite. Garnet.  
Allophane. Hydrous Silicate of Alumina, *b*.  
Almandine. Garnet.  
Alum. Sulphate of Alumina and Potash, *a*.  
Alumina. Fluide.  
Hydrate.  
Mellate.  
Native.  
Phosphate.  
Silicate.  
Hydrous Silicate.  
Sulphate.  
Alum Stone. Sulphate of Alumina and Potash, *b*.  
Amalgam. Native Mercury, *b*.  
Amazon Stone. Green Felspar.  
Amber. Carbon, *F*.  
Amblygonite.  
Amethyst. Purple Quartz.

VOL. VI.

Amianthinite. Amphibole.  
Amanthoide. Amphibole.  
Amianthus. Amphibole.  
Amiatite. Fiorite.  
Ammonia. Murate.  
Sulphate.  
Anapelite.  
Amphibole.  
Amphigene. Leucite.  
Amphodelite. Labradorite.  
Analcime.  
Anatase. Oxide of Titanium, *a*.  
Andalusite. Silicate of Alumina, *c*.  
Andeolite. Hornblende.  
Anhydrite. Sulphate of Lead.  
Anhydrite. Anhydrous Sulphate of Lime.  
Ankerite. Carbonate of Lime and Iron.  
Anorthite.  
Anthophyllite.  
Anthracite. Coal, *a*.  
Anthraconite. Columnar Carbonate of Lime.  
Antimonial Silver. Stibiuret of Silver.  
Antimony. Arsenical.  
Native.  
White.  
Sulphuret.  
Grey.  
Black.  
Red.  
Antrimonite. A supposed new Mineral from Ireland.  
Apatite. Phosphate of Lime.  
Aphrite. Pearly Carbonate of Lime.  
Aphrizite. Tourmaline.  
Aplome.  
Apophyllite.  
Apyrite. Red Tourmaline.  
Aquamarine. Emerald.  
Arendahite. Epidote.  
Arfwedsonite.  
Arkosite. Scapolite.  
Arragonite. Hard Carbonate of Lime.  
Arsenic, Native.  
Oxide.  
Sulphuret.  
Asbestos. Amphibole.  
Aschlei. Native Bismuth.  
Asparagus Stone. Phosphate of Lime.  
Asphaltum. Bitumen, *f*.  
Asteria. Corundum.  
Atacamite. Chloride of Copper.  
Augite. Pyroxene.  
Augustite. Phosphate of Lime.  
Auralite.  
Automalite. Aluminate of Zinc.  
Avanturine. Quartz.  
Axe-stone. Jade.  
Axinite.

**Mineralogy.** Azotomous Arsenical Pyrites. Hüttenbergite.  
 Azotomous Iron. Titanate of Iron, *c*.  
 Azabache. • Coal, Jet.  
 Asurite.

## B.

Babingtonite.  
 Baikalite. Pyroxene.  
 Baldogee. Green Earth.  
 Barbadoes Tar. Petroleum.  
 Bardighione. Anhydrous Sulphate of Lime.  
 Barolite. Carbonate of Barytes.  
 Baroselenite. Sulphate of Barytes.  
 Barruelite. Carbonate of Soda and Lime, *a*.  
 Barystrontianite  
 Barytes, Carbonate.  
 Sulphate  
 Barytocalcite. Carbonate of Barytes and Lime.  
 Baryto-fluorite. Sulphate of Barytes and Fluoride of Lime.  
 Basanite. Silica, *b*.  
 Bastnaïte. Seleniuret of Bismuth and Tellurium.  
 Baumerite. Chloride of Mercury.  
 Beaume de Monie. Asphaltum.  
 Beekite, a Mineral not described, said to be Silicate of Alumina.  
 Beilstein. Jade.  
 Bell-metal Ore. Sulphuret of Tin and Copper.  
 Bergmannite.  
 Bergmehl.  
 Bernhardtite. Sulphate of Potash.  
 Bernstein. Amber.  
 Berthierite. Sulphuret of Antimony and Iron.  
 Beryl. Emerald.  
 Berzelite. Chloride of Lead, *c*.  
 Bendantite. Oxide of Iron and Lead.  
 Bildstein. Agalmatolite.  
 Bimstein. Pumice.  
 Biotine.  
 Bismuth, Arseniuret.  
 Carbonate  
 Native.  
 Oxide.  
 Seleniuret.  
 Sulphuret.  
 Sulpho-telluret.  
 Bismuth-blende. Silicious Carbonate of Bismuth.  
 Bismuth glance. Sulphuret of Bismuth.  
 Bismuthic Silver. Sulphuret of Silver, Lead, and Bismuth.  
 Bitterspar. Carbonate of Lime and Magnesia.  
 Bitumen. Carbon, *C*.  
 Black Chalk. Ampelite.  
 Black Copper. Oxide of Manganese, Iron, and Copper.  
 Black Lead. Carburet of Iron.  
 Blattererz. Tellurium.  
 Bleimere. Arsenate of Lead.  
 Bleischimmer. Sulphuret of Lead and Antimony.  
 Bleischweif. Compact Sulphuret of Lead.  
 Blende. Sulphuret of Zinc.  
 Blütsinter. Quartz. Sand-tubes.  
 Bloodite. Sulphate of Magnesia and Soda.  
 Bloodstone. Quartz. Calc-dony.  
 Bole. Hydrus Silicate of Alumina, *k*.  
 Bolide. Native Meteoric Iron.  
 Bolognian Spar. Sulphate of Barytes.  
 Boracic Acid.  
 Boracite. Borate of Magnesia.  
 Borax. Borate of Soda.  
 Borch. Carbonate of Soda.  
 Bornite. Sulpho-telluret of Bismuth.  
 Botryogene. Red Sulphate of Iron.  
 Botryolite. Borosilicate of Lime, *c*.  
 Bournoinite. Sulphuret of Lead, Antimony, and Copper.  
 Bovelite.  
 Bovey Coal. Carbon.  
 Braardite. Red Silver, *a*.  
 Braunite. Oxide of Manganese, *f*.  
 Breislakite.  
 Breunnerite. Carbonate of Magnesia and Iron.  
 Brewsterite.  
 Brittle Silver. Polybasite.  
 Brochantite. Sulphate of Copper, *b*.  
 Brongniartite. Glauberite.  
 Bronzite.

Brookite. Oxide of Titanium, *c*. ?  
 Brown Iron Ore. Hydrate of Iron.  
 Brownspar. Carbonate of Iron.  
 Brucite. Condroidite.  
 Brunon. Siliceo-calcareous Oxide of Titanium.  
 Bucholzite. Silicate of Alumina, *c*.  
 Bucklandite.  
 Buntkupfererz. Purple Copper  
 Bustamite. Pyroxene ?  
 Byssolite. Amphibole.

## C.

Cacholong. Hydrus Quartz.  
 Cadmium.  
 Calait. Hydrate of Alumina, *c*.  
 Calamine. Carbonate of Zinc.  
 Calamine, Electric. Silicate of Zinc.  
 Calamite. Amphibole.  
 Calcedony. Silica, *b*.  
 Calcite. Crystallized Carbonate of Lime.  
 Caledonite. Cupreous Sulphate-tri-carbonate of Lead  
 Candite. Black Spinnelle.  
 Cantabite. Yellowish-green Quartz.  
 Carbone Acid.  
 Carbyncle. Garnet.  
 Caranthin. Amphibole.  
 Caranthite. Molybdate of Lead.  
 Carnehan. Silica, *b*.  
 Carphosiderite. Phosphate of Iron, *b*.  
 Catsye. Quartz containing Asbestos.  
 Cavolinite.  
 Cawk. Sulphate of Barytes.  
 Celestine. Sulphate of Strontia.  
 Ceramian Sinter. Quartz, Sand-tubes.  
 Ceramite. Jade, Nephrite.  
 Cereolite.  
 Cerine. Silicate of Cerium and Iron, *b*.  
 Cerite. Silicate of Cerium and Iron, *a*.  
 Cerium. Carbonate.  
 Fluoride.  
 Silicate.  
 Chabasie.  
 Chalcobite. Phosphate of Uranium and Copper.  
 Chalcosiderite. Fibrous green Iron Earth.  
 Chalk. Earthy Carbonate of Lime.  
 Chamosite. Oxidulous Iron.  
 Chelustoidite. Scapolite.  
 Chnastolite.  
 Childrentite.  
 Chlorite. Tale.  
 Chloromelan. Cronstedtite.  
 Chloropal. Silicate of Iron, *c*.  
 Chlorophane.  
 Chlorophane. Fluoride of Lime.  
 Christianite. Anorthite.  
 Chrome. Oxide.  
 Chrysoberyl.  
 Chrysocolla. Silicate of Copper, *b*.  
 Chrysolite. Peridot.  
 Chrysoprase. Silica, *b*.  
 Chusite. Decomposing granular Peridot  
 Cinnolite. Hydrus Silicate of Alumina, *c*.  
 Cinnabar. Sulphuret of Mercury.  
 Cinnamon-stone. Garnet.  
 Clay. Hydrus Silicate of Alumina, *c*.  
 Claystate. Clay  
 Claystone. Clay.  
 Cleavelandite.  
 Coal. Carbon, *B*.  
 Cobalt, Arseniate.  
 White.  
 Grey.  
 Earthy  
 Sulphate.  
 Sulphuret.  
 Coccolite. Graptol Pyroxene.  
 Cockle. Tourmaline  
 Colophonite. Garnet.  
 Columbite. Tantalite.  
 Comptonite.  
 Condroidite.  
 Condurrite. Arseniate of Copper

**Minerology**

**Mineralogy.** Confetto di Tivoli. Caletuffe

Copal, Fossil. Bitumen.

Copper, Arseniate.

Arseniuret.

Carbonate.

Chloride.

Native.

Oxide.

Phosphate.

Seleniuret.

Silicate.

Sulphate.

Sulphuret.

\*Copper Nickel. Arseniuret of Nickel

Corallenez. Hepatic Sulphuret of Mercury.

Corundum. Native Alumina, *a*.

Cottonerz. White Tellurium.

Couzeranite. Felspar.

Crichtonite. Titanate of Iron, *f*.

Crispite. Titanium, Rutile.

Crocalite. Globular radiated red Natrolite?

Cronstedtite. Silicate of Iron, *a*.

Croceite. Chastolite.

Cryolite.

Cubicite. Analcime.

Culebrite. Biseleniuret of Zinc, &c.

Cummingtonite. Amphibole.

Cyanite. Kyanite

Cymophane. Chrysoberyll

Cyprine. Blue Idocrase

## D

Dapeche. Bitumen.

Datholite. Borosilicate of Lime, *a*.

Damite. Red Tourmaline.

Davite. Sulphate of Alumina, *b*.

Davyne

Delphinite. Epidote.

Deodolite. Pechstone

Desanne.

Devonite. Phosphate of Alumina

Dialogite. Carbonate of Manganese.

Diamond. Carbon, *A*.

Diaspore. Hydrate of Alumina, *a*.

Dichroite.

Diopside. Pyroxene.

Diopase. Silicate of Copper, *a*

Diploite. Lathroite.

Dipyre.

Dislute.

Disthene. Kyanite.

Dolomite. Granular Magnesian Carbonate of Lime.

Dragonite. Crystallized Quartz.

Dyskolite. Saussurite.

Dysodile. Coal, *d*

## E

Edingtonite.

Egerane. Idocrase

Egyptian Pebble. Quartz, Jasper.

Eisenkiesel. Ferruginous Quartz.

Ekebergite. Scapolite.

Elaeolite.

Elatente. Bitumen, *c*.

Electum. Gold, *b*.

Emerald.

Emery. Granular Corundum

Eudellhone. Sulphuret of Lead, Antimony, and Copper.

Epidote.

Epistilbite.

Epsomite. Sulphate of Magnesia.

Ercinite. Harminotome.

Ermite. Arseniate of Copper.

Erlauite.

Esmarkite. Silicious Borate of Lime.

Essonite. Garnet.

Euchroite. Arsenate of Copper.

Euchysanderite. Achmita

Eucrase.

Eudyalite.

Eukairite. Seleniuret of Silver and Copper.

Fahlunite.

Fahlore. Sulphuret of Copper, Iron, &c., *A*.

Fassaite. Pyroxene.

Felspar.

Felstein. Compact Felspar.

Fergusonite. Tantalate of Yttria and Cerium.

Fetstein. Elaeolite.

Fibrolite. Silicate of Alumina, *d*.

Figure-stone. Agalmatolite.

Fiorite. Hydrous Quartz.

Fish-eye-stone. Apophyllite

Flint. Silica, *b*

Flockenerz. Arseniate of Lead.

Flos-terpi. Coralloidal Arragonite.

Fluellite. Alumina, *a*.

Flukan. Clay.

Fluor Spar. Fluato of Lime.

Forsterite.

Fossil Copal. Carbon, *E*.

Fowlerite. Bisilicate of Manganese.

Franklinite. Oxide of Iron, Zinc, and Manganese.

Frugardite. Reddish Idocrase, containing Magnesia

Fulgurite. Sand-tubes, Quartz

Fuller's Earth. Hydrous Silicate of Alumina, *f*.

Fuscite.

## G

\*Gabbionite.

Gado'mite. Silicate of Yttria and Iron.

Gahnite. Aluminate of Zinc.

Galena. Sulphuret of Lead.

Gallizenstein. Sulphate of Zinc.

Gallzinit. Oxide of Titanium.

Garnet.

Gay Lussite. Carbonate of Soda and Lime, *a*.

Geatrace. Coal.

Gehlenite.

Geysenite. Hydrous Quartz.

Gibbsite. Hydrate of Alumina, *b*.

Giesekite.

Gioberthite. Carbonate of Magnesia.

Ginsol. Quartz, Opal.

Gismondum. Zeagonite.

Glance Copper. Sulphuret of Copper.

Glauber Salt. Sulphate of Soda

Glauberite. Sulphate of Soda and Lime.

Glaucolite.

Gmelinite.

Goethite. Oxide of Iron, *b*

Gold

Gotlandite. Arsenate of Lead

Grammatite. Amphibole.

Grammite. Silicate of Lime.

Graphic Ore. Tellurium

Graphite. Carburet of Iron.

Green Earth.

Green Iron Earth. Silicate of Iron, *f*.

Greenlandite. Garnet.

Gregorite. Ferriferous Oxide of Titanium.

Grenatite. Staurolite.

Grossularia. Garnet.

Grunerite. Sulphate of Strontian and Barytes.

Gummistern. Quartz, Hyalite.

Gurhofian. Compact Magnesian Carbonate of Lime.

Gypsum. Sulphate of Lime.

## H

Haidingerite. Arseniate of Lime, *b*.

Hallite. Websterite.

Hallotricum. Sulphate of Magnesia.

Halloysite. Hydrous Silicate of Alumina, *d*.

Harmotome.

Harringtonite.

Hartmannite. Sulphuret of Antimony and Nickel.

Hatchettine. Carbon, *G*.

Hausmannite. Oxide of Manganese, *c*.

Haüyno

Haydenite. Heulandite.

Haytorite. Quartz.

Hedenbergite.



Mineralogy. Heliotrope. Silica, *b*

Helvin.

Hematite. Brown. Hydrous Oxide of Iron

Red. Oxide of Iron, *c*.

Henkelite. Sulphuret of Silver.

Hepatite. Barytes.

Herderite.

Herronite. Iodide of Silver.

Herschellite.

Hetspozite. Phosphate of Manganese and Iron, *b*.

Hollandite.

Highgate Resin. Carbon, *E*.

Hisingerite.

Hjogaute. Natrolite.

Honey-store. Mellite.

Hopite. Zinc ? *a*.

Hornblende. Amphibole.

Horn Silver. Chloride of Silver.

Hornstone, Fusible. Compact Felspar.

Infusible. Quartz.

Humboldtite. Somervillite.

Humboldtine. Oxalate of Iron.

Humboldtite. Boro-silicate of Lime, *b*

Humite.

Huraultite. Phosphate of Manganese and Iron, *c*.

Hüttenbergite. Sulphuret of Iron and Arsenic.

Hyacinth. Zircon.

Hyalite. Hydrous Quartz.

Hyalosiderite. Pseudot.

Hydrogen Gas.

Hydrargillite. Phosphate of Alumina.

Hydrophane. Hydrophane Quartz.

Hydrolite. Gmelinite.

Hydropite. Silicate of Manganese.

Hydro-silicite. Quartz. Appendix.

Hypersthene.

## I.

Iberite.

Ice-spar. Anorthite.

Icthyophthalmite. Apophyllite

Idocrase.

Igda. Jade.

Igloite. Arragonite.

Illudite. Epidote.

Imexite.

Ilvite. Yente.

Indanite.

Indicolite. Blue Tourmaline.

Inolite. Stalactitic Carbonate of Lime.

Iolite. Dichroite.

Iridium.

Iron, Aluminate ?

Arsenate.

Carbonate.

Carburet.

Chromate.

Native.

Native Steel.

Oxalate.

Oxydulous.

Oxide.

Hydrate.

Phosphate.

Scheelate.

Silicate.

Sulphate.

Sulphuret.

Titanate.

Iron Pitch Ore. Iron Sinter. Pittzite ?

Iron Sand. Titanate of Iron, *a*.Iserine. Titanate of Iron, *b*.

Isopyre.

Ittnerite.

## J.

Jade.

Jamesonite. Sulphuret of Antimony, Lead, and Iron.

Jargoon. Zircon.

Jasper. Silica, *b*.

Jeffersonite. Pyroxene

Jet. Wood Coal.

Johannite. Sulphate of Uranium and Copper.

Johnite. Calcite.

Johnstonite. Vanadate of Lead.

## K.

Kakoxene.

Kali. Potash.

Kaolin. Hydrous Silicate of Alumina, *p*

Karabe. Amber.

Kapholite.

Kaphosiderite. Phosphate of Iron

Karstenite. Anhydrous Sulphate of Lime,

Karstin. Schiller Spar.

Kestekil. Carbonate of Magnesia.

Keraphyllite. Amphibole.

Keratite. Quartz, Hornstone.

Keratophyllite. Amphibole.

Kerolite.

Kerstenite. Cobalt, Bismuth, and Arsenic.

Kil. Silicious Carbonate of Magnesia ?

Killenite.

Killkeff. Silicious Carbonate of Magnesia ?

Klaprothite. Azurite.

Kobelite. Sulphuret of Manganese.

Kohlerite. Carbonate of Manganese.

Kollyrite. Hydrous Silicate of Alumina, *a*.Konigine. Sulphate of Copper, *c*.

Konilite. Quartz.

Konite. See Couite.

Koreite. Agalmatolite.

Koupholite. Prehnite.

Kupferindig. Sulphuret of Copper and Iron, *b*.

Kupferschaum. Carbonate of Copper and Zinc.

Kyanite. Silicate of Alumina, *a*.

## L.

Labrador Hornblende. Hypersthene.

Labradorite.

Lanarkite. Sulphato-carbonate of Lead.

Lapis Lazuli. Lazulite.

Lardite. Agalmatolite.

Lasionite. Wavellite.

Lathalite. Haubyne.

Latrobite.

Laumontite

Lava

Laxmannite. Chloride of Silver.

Lazulite.

Lead, Aluminate

Arsenate.

Carbonate.

Chloride.

Chromate.

Molybdate.

Native.

Oxide.

Phosphate.

Scheelate.

Selenuret.

Sulphate.

Sulphato-carbonate.

Sulphuret.

Vanadate.

Leelite.

Lemanite. Compact Felspar.

Lemnian Earth. Hydrous Silicate of Alumina, *a*.Lenzinite. Hydrous Silicate of Alumina, *c*.Lepidolite. Mica, *c*.

Lepidokrokite. Hydrous Oxide of Iron.

Leucite.

Leucolite. Dipyre.

Libethenite. Phosphate of Copper.

Lievrite. Jenite.

Ligurite.

Lignite. Coal, *c*

Lillalite. Lepidolite.

Limbalite.

Lime, Arseniate.

Boro-silicate.

Mineralogy

Mineralogy. Lime, Carbonate.

Aragonite.  
Fluate.  
Native.  
Phosphate.  
Scheelate.  
Silicate.  
Sulphate.  
Titanate.

Limonite. Oxide of Iron.  
Linarite. Cupreous Sulphate of Lead.  
Linsenerz. Arseniate of Copper.  
Lipalite. Quartz, Flint.  
Listerite. Sulphate of Zinc.  
Lithospor. Radiated Sulphate of Barytes.  
Lithomarge. Hydrated Silicate of Alumina, &c.  
Liver Ore. Sulphuret of Mercury.  
Loboite. Idocrase.  
Lodalite. Compact Felspar.  
Lotalite. Amphibole.  
Lumachella. Shelly Carbonate of Lime.  
Lydian-stone. Quartz.  
Lythrones. Elaeolite.

M

Macle. Chastolite.  
Maclelanite. Sillimanite.  
Maclureite. Condroidite.  
Madrepore. Columnar Carbonate of Lime.  
Magnesia. Borate.  
Carbonate.  
Hydrate.  
Phosphate.  
Silicate.

Magnetic Iron. Oxidulous Iron.  
Magnesite. Carbonate of Magnesia.  
Malachite. Carbonate of Copper.  
Malaculite. Pyroxene.  
Maltha. Bitumen, *d*.  
Manganese. Arseniuret?

Carbonate.  
Oxide.  
Phosphate.  
Silicate.  
Sulphuret.

Manganite. Oxide of Manganese, *a*.  
Marble. Compact Carbonate of Lime.  
Marecanti. Obsidian.  
Margarite. Mica, *d*.  
Markasite. Arsenical Sulphuret of Iron.  
Marl. Aluminous Lime.  
Marmolite. Silicate of Magnesia, *a*.  
Mascagnin. Sulphate of Ammonia.  
Massicot. Yellow Oxide of Lead.  
Mauritite. Phosphate of Alumina and Ammonia.  
Meerschaum. Silicate of Magnesia, *d*.  
Meionite.  
Melanite. Black Garnet.  
Melanteria. Sulphate of Iron.  
Mellilite.  
Mellite. Mellate of Alumina, *a*.  
Menachantite. Titanate of Iron, *c*.  
Mengite.  
Menilite. Hydrated Quartz.  
Mercury. Chloride.

~~Native~~ Sulphuret.  
Mesitine Spar. Carbonate of Lime and Iron?

Mesola. Chabasie.

Mesolite.

Mesotype.

Meteorite. Native Iron.

Miargyrite. Red Silver, *b*.

Mica.

Micaceous Iron. Oligiste Iron.

Micaphyllite. Andalusite.

Micrelle. Pinite or Scapolite.

Miamite. Magnesian Carbonate of Lime.

Mineral Adipocire. Hatchetite.

Minium. Red Oxide of Lead.

Mispickel. Sulpho-arseniuret of Iron.

Misy. Persulphate of Iron.

Mocha Stone. Quartz, Dendritic Agate.

Mohsite. Titanate of Iron, *g*.

Molarite. Quartz, Buhrstone.

Molybdan Silver. Sulpho-telluret of Silver and Bismuth.

Molybdenite. Sulphuret of Molybdenum.

Molybdenum. Oxide.

Sulphuret.

Monacite. Mengite.

Monticellite.

Moon-stone. Felspar.

Mornite.

Moroxite. Phosphate of Lime.

Mountain Cork.

Leather. } Asbestos.

Wood. }

Mountain Meal. Bergmehl.

Mountain Soap. Hydrated Silicate of Alumina.

Mountain Tallow. Hatchetite.

Müller's Glass. Quartz, Hyalite.

Mundie. Iron Pyrites.

Murchisonite.

Muriacite. Anhydrous Sulphate of Lime.

Muriate of Silver. Chloride of Silver.

Muriatic Acid.

Muricallite. Magnesian Carbonate of Lime.

Murindo. Bitumen, *c*.

Murio-carbonate of Lead. Chloride of Lead, *b*.

Mussite. Pyroxene.

Myrsen. Silicious Hydrate of Magnesia.

N.

Naphtha. Bitumen, *a*.

Naphthaline. Carbon, H.

Napoleonite. Globular Felspar.

Natrolite. Mesotype.

Natron. Soda.

Necronite. Felspar?

Needle-ore. Sulphuret of Bismuth, Lead, and Copper.

Needle-stone. Mesolite.

Neopetre. Quartz, Hornstone.

Nepheline.

Nephrite. Jade.

Nickel. Arseniate.

Arseniuret.

Oxide.

Sulphuret.

Nigrine. Titanate of Iron, *d*.

Nitro. Nitrate of Potash.

Nontronite. Silicate of Iron, *d*.

Nosm. Spinellane.

Nuttallite.

O.

Obsidian.

Ochre. Oxide of Iron.

Ochrone. Oxide of Cerium.

Octahedrite. Oxide of Titanium, *a*.

Odent, probably Black Mica.

Oisante. Oxide of Titanium.

Okenite. Silicate of Lime, *b*.

Oldhamite. Saccharous Sulphate of Alumina, *a*.

Oligiste Iron. Oxide of Iron, *a*.

Olivinite. Arsenate of Copper.

Olivine. Peridot.

Onegite. Titanium?

Onyx. Calcedony.

Oolite. Globular Carbonate of Lime, *b*.

Opal. Hydrated Quartz.

Ophite. Serpentine.

Orpiment. Yellow Sulphuret of Arsenic.

Orthite. Silicate of Cerium, Iron, Alumina, and Lime, *a*.

Orthose. Felspar.

Osmelite.

Osmium.

Osteocolla, incrusting Carbonate of Lime.

Ostranite. Zircon?

Otrellite. Schiller Spar?

Oxahoeite. Apophyllite.

Oxalite. Oxalate of Iron.

Mineralogy.

## Mineralogy.

## P

**Pagodite.** Agalmatolite.  
**Palladium.**  
**Pamplonite.** Molybdate. &c. of Lead  
**Parantkine.** Scapolite.  
**Pargasite.** Amphibole.  
**Paulite.** Hypersthene.  
**Pearl Spar.** Magnesian Carbonate of Lime.  
**Pearlstone.**  
**Peat.** Coal.  
**Pechuran.** Ferriferous Oxide of Uranium.  
**Pektolite.**  
**Belhome.** Dichroite.  
**Pelokonite.** Copper, composition unknown.  
**Pentacrasite.** Pyroxene.  
**Pendot.**  
**Petalite.**  
**Petroleum.** Bitumen, *b.*  
**Petuntzé,** probably Quartz. (Chinese.)  
**Phanpocolite.** Arsenate of Lime, *a.*  
**Pharmacosiderite.** Cubic Arseniate of Iron.  
**Phenakite.** A new Mineral not described.  
**Phillipsite.** Zeagonite.  
**Pholerite.** Hydrous Silicate of Alumina, *a.*  
**Phosphato-arseniate of Lead.** Phosphate of Lead, *b.*  
**Phosphorite.** Fibrous Phosphate of Lime.  
**Photizite.** Silicious Carbonate of Manganese.  
**Physalite.** Topaz.  
**Picotite.** Tourmaline.  
**Pierite.** Magnesian Carbonate of Lime.  
**Picrolite.**  
**Picrosime.**  
**Pictite.** Turnerite?  
**Pierre de Timpes.** Anhydrous Sulphate of Lime.  
**Pimelite.** Oxide of Nickel.  
**Pingute.**  
**Pinite.**  
**Pisolite.** Globular Carbonate of Lime, *a.*  
**Pistazite.** Epidote.  
**Pitchblende.** Ferriferous Oxide of Uranium.  
**Pitchstone.**  
**Pittzite.** Arsenate of Iron?  
**Plagiomite.** A new Mineral not described.  
**Plasma.** Silica, *b.*  
**Platina.**  
**Picropaste.** Spinnelle.  
**Pleuroklas.** Wagnente.  
**Plombagine,** or  
**Plomb-gomme.** Aluminate of Lead.  
**Plumbago.** Graphite.  
**Plumbo-calcite.** Carbonate of Lime and Lead.  
**Pluranium.**  
**Poilit.** Pitchstone.  
**Polishing Stone.** Earthy Quartz.  
**Polybasite.** Red Silver, *c.*  
**Polychrome.** Phosphate of Lead.  
**Polyhalite.**  
**Polyunguine.** Tantalate of Yttria, Zircon, and Lime.  
**Polyxen.** Platina.  
**Pomalilite.**  
**Porcelain Clay.** Kaolin.  
**Porcelain Jasper.** Quartz Jasper.  
**Potash.** Nitrate.  
**Sulphate.**  
**Potstone.** Compact Tale.  
**Pounxa.** Borate of Soda. (Chinese.)  
**Prase.** Green Quartz.  
**Prateolite.** A new Mineral not described.  
**Prothégite.** Green Pyroxene.  
**Prunierite.** Grey Carbonate of Lime.  
**Pseudo-Sommeite.** Bovelite.  
**Pseudomelane.** Oxide of Manganese, *d.*  
**Pycnite.** Topaz.  
**Pyraphrolite.** Pitchstone.  
**Pyrrargillite.**  
**Pyrencite.** Black Garnet.  
**Pyrgom.** Pyroxene.  
**Pyrites.** Sulphuret of Copper, or of Iron.  
**Pyrochlore.** Titanate of Lime, &c.  
**Pyrolusite.** Oxide of Manganese, *c.*  
**Pyromorphite.** Phosphate of Lead.  
**Pyrope.** Garnet.

## Pyrophyllite.

Pyrophysalite. Topaz.  
 Pyrothite. Silicate of Cerium, Iron, Alumina, and Lime, *a.*  
 Pyrosiderite. Oxide of Iron *b.*  
 Pyrosmahte. Pyrodmalite.  
 Pyrosmalite.  
 Pyroxene.

## Q.

Quartz. Silica.  
 Quartz, Hydrous. Silica.  
 Quicksilver. Mercury.

## R.

Radiolite. Bergmannite.  
 Rapidolite. Scapolite.  
 Ratofkat. Earthy Fluate of Lime.  
 Razoumoffskiu. Silicious Carbonate of Lime.  
 Realgar. Red Sulphuret of Arsenic.  
 Retinasphaltum. Carbon, *D.*  
 Retinite. Pitchstone.  
 Reussite. Sulphate of Soda and Magnesia.  
 Rhemite. Hydrous Phosphate of Copper.  
 Rhetizite. Kyanite.  
 Rhodium.  
 Rhodochrosite. Carbonate of Manganese.  
 Rhodonite. Silicious Carbonate of Manganese.  
 Rhutenium.  
 Riverolite. Nitrate of Soda.  
 Riohte. Biseleniuret of Zinc, &c.  
 Rock Salt. Chloride of Sodium.  
 Rohwand. Carbonate of Lime and Iron.  
 Romanzovite. Garnet.  
 Romeite. Sulphuret of Silver and Antimony.  
 Roschite. Arsenate of Cobalt, *b.*  
 Rothoffite. Garnet.  
 Rotten-stone. Alumina with Silica and Carbon.  
 Robellan. Mica, *c.*  
 Rubellite. Tourmaline.  
 Rubinglumner. Hydrous Oxide of Iron.  
 Ruby. Spicelle and Corundum.  
 Rutile. Oxide of Titanium, *b.*  
 Ryakolite. Glassy Felspar.

## S.

Sagenite. Oxide of Titanium.  
 Sahlite. Pyroxene.  
 Sakammomac. Murate of Ammonia.  
 Salt. Common. Murate of Soda.  
 Sandin. Felspar.  
 Sappare. Cyanite.  
 Sapphure. Blue Corundum.  
 Sapphirine.  
 Sarcolite. Analime.  
 Sard. Silica, *b.*  
 Sardonyx. Quartz, Agate.  
 Sassolin. Boracic Acid.  
 Satin Spar. Fibrous Arragonite.  
 Sauspate. Epidote.  
 Saussurite. Jade.  
 Scapolite.  
 Scabroite. Hydrous Silicate of Alumina, *a.*  
 Schalstem. Silicate of Lime.  
 Schererite. Carbon, *I.*  
 Schieffer-spar. Foliated Carbonate of Lime.  
 Schiller-spar.  
 Schorl.  
 Schorl. Tourmaline.  
 Schutzite. Sulphate of Strontian.  
 Scolozite. Needlestone.  
 Scorza. Granular Epidote.  
 Selbite. Carbonate of Silver.  
 Selenite. Sulphate of Lime.  
 Selenium.  
 Semeline. Siliceo-calcareous Oxide of Titanium.  
 Serpentine. Silicate of Magnesia, *c.*  
 Severite. Hydrous Silicate of Alumina, *c.*  
 Shepardite. Hydrate of Magnesia.  
 Siberite. Red Tourmaline.  
 Siderite. Blue Quartz.

## Mineralogy

Mineralogy.

Sidero-graphite. Graphite, *b*.  
 Sideroschist. Silicate of Iron, *b*.  
 Silicious Spar. Cleavelandite.  
 Sillimanite. Silicate of Alumina, *b*.  
 Silver. Stiburet.  
     Carbonate.  
     Chloride.  
     Iodide.  
     Native.  
     Selenuret.  
     Sulphuret.  
     Sulpho-telluret.  
 Silver Kupfer Glanz. Sulphuret of Silver and Copper.  
 Sinople. Quartz Jasper.  
 Skorian. Aluminate of Iron?  
 Skorodite. Arsenical Iron.  
 Skorza. Granular Epidote.  
 Smaragdite. Amphibole.  
 Smithsonite. Silicate of Zinc.  
 Soapstone. Steatite.  
 Soda. Borate.  
     Carbonate.  
     Murate.  
     Nitrate.  
     Sulphate.  
 Sodaite. Fettstein?  
 Sodahite.  
 Somervillite.  
 Sommitte. Nepheline.  
 Somonite. Corundum.  
 Sordawallite.  
 Spartaite. Red Oxide of Zinc.  
 Speckstein. Steatite.  
 Specular Iron. Oxide of Iron, *a*.  
 Sphaerulite.  
 Spheue. Silico-calcareous Oxide of Titanium.  
 Sphero-siderite. Carbonate of Iron.  
 Sphingid. Bole?  
 Spinelane.  
 Spinnelle.  
 Spinnelle, and  
 Spinthere. Silico-calcareous Oxide of Titanium.  
 Spodumene.  
 Spreiustein. Bergmannite.  
 Stahlstein. Carbonate of Iron.  
 Stalactite. Fibrous Carbonate of Lime.  
 Stanzite. Andalusite.  
 Staurolite.  
 Staurotide. Staurohite.  
 Steatite. Silicate of Magnesia, *c*.  
 Steatoid. Serpentine.  
 Steinheilite. Dichroite.  
 Stenmark. Lithomarge.  
 Stellite.  
 Sternbergite. Flexible Silver. Sulphuret of Silver and Iron.  
 Stilbite.  
 Stilpnosiderite. Hydrated Oxide of Iron.  
 Strömite. Bisilicate of Manganese.  
 Strommite. Barytiferous Carbonate of Strontian.  
 Strontia. Carbonate.  
     Sulphate.  
 Strontianite. Carbonate of Strontian.  
 Stylobat. Gehlenite.  
 Succin. Amber.  
 Succinite. Granular Yellow Garnet.  
 Sulphur.  
 Sulphuric Acid. Sulphur *b*.  
 Sunstone. Felspar?  
 Surturbrand. Wood Coal.  
 Susannite. Sulphato-tri-carbonate of Lead.  
 Swaga. Borate of Soda.  
 Sylvan. Tellurium.

T.

Tabular Spar. Silicate of Lime, *a*  
 Talc.  
 Talc Zographique. Green Earth.  
 Tankelite. Phosphate of Yttria.  
 Tantalite.  
 Tautolite.  
 Telesie. Corundum.

Mineralogy.

Tellurium. Native.  
     Graphic.  
     Yellow.  
     Black.  
 Tennantite. Sulphuret of Copper, Iron, &c. *B*.  
 Tephroite. Zinc? *b*.  
 Tetraclase. Scapolite.  
 Terra de Siena. Bole?  
 Terra Sigillata. Lemnian Earth?  
 Terre de Mamarosch. Earthy Phosphate of Lime.  
 Thallite. Epidote.  
 Tharandite. Magnesian Carbonate of Lime.  
 Thenardite. Anhydrous Sulphate of Soda.  
 Thomsonite.  
 Thorite.  
 Thraulite. Silicate of Iron, *c*.  
 Thumite. Axinite.  
 Tin. Oxide.  
     Sulphuret.  
 Tinstone. Oxide of Tin  
 Tinder Ore. Antimony.  
 Tincal. Borate of Soda.  
 Titanium. Oxide  
 Tofsate. Alum Stone.  
 Topaz.  
 Topazolite. Yellow Garnet.  
 Torbente. Phosphate of Uranium.  
 Torrelite. Cerium?  
 Touchstone. Silica, *L*.  
 Tourmaline.  
 Travertino. Sedimentary Carbonate of Lime.  
 Tremolite. Amphibole.  
 Triclasite. Fahluite.  
 Triphane. Spodumene.  
 Tripoli. Earthy Quartz.  
 Trona. Carbonate of Soda, *c*.  
 Tufa. Encrusting Carbonate of Lime.  
 Tungsten. Scheelite of Lime.  
 Turkey Stone. Novaculite.  
 Turverite.  
 Turquoise. Calcite.  
 Tyronite. Azurite.

U.

Ullmannite. Phosphate of Manganese and Iron, *a*.  
 Umber. Oxide of Iron and Manganese.  
 Uramite. Phosphate of Uranium.  
 Uranium. Oxide.  
     Phosphate.  
     Sulphate.

V.

Vanadium.  
 Vargasite.  
 Variolite. Globular Felspar?  
 Varvicite. Oxide of Manganese, *b*.  
 Vauquelinite. Chromate of Lead and Copper  
 Velvet Copper. Silicate and Sulphate of Copper.  
 Vestuvian. Idocrase.  
 Vivianite. Phosphate of Iron, *a*.  
 Volcanic Glass. Obsidian.  
 Vorpahite. Azurite.  
 Vulcanite. Augite.  
 Vulpinite. Anhydrous Sulphate of Lime.

W.

Wad. Earthy Oxide of Manganese.  
 Wærthite.  
 Wagnerite. Phosphate of Magnesia.  
 Wallerite. Lenzinite.  
 Welmstedite. Carbonate of Iron and Magnesia.  
 Wandstein. Carbonate of Lime and Iron.  
 Wavellite. Phosphate of Alumina.  
 Websterite. Sulphate of Alumina, *a*  
 Weissite.  
 Wernerite.  
 Wernerite. Scapolite.  
 Wiluite. Idocrase.

**Mineralogy.** Withamite.  
 Witharite. Carbonate of Barytes.  
 Wolfram. Scheelate of Iron and Manganese.  
 Wolkonskoit.  
 Wollastonite. Silicate of Lime, &c.  
 Woldyn. Sulphate of Barytes.

## X.

Xanthite. Idocrase.  
 Xantholite. Probably Garnet.

## Y

Yanolite. Axinite.  
 Yellow Earth.  
 Yenite. Silicate of Iron and Lime.  
 Ytterbite. Gadolinite.  
 Yttria. Phosphate.  
       Silicate.  
       Tantalate.  
       Titaniate.

Yttrocrite. Cerium.  
 Yttrotantalite. Tantalate of Yttria, &c.  
 Yu. Prehnite?

## Z.

Zala. Borate of Soda. (Thibet.)  
 Zinc. Aluminate.  
       Carbonate.  
       Oxide.  
       Seleniuret  
       Sulphate.  
       Sulphuret.  
 Zinkenite. Sulphuret of Antimony and Lead  
 Zircon. Silicate of Zirconia.  
 Zoisite.  
 Zurlite.  
 Zurlonite. Zurlite.

**Mineralogy**

# G E O L O G Y .

## CHAPTER I .

### PROGRESS AND PRINCIPLES OF THE SCIENCE.

Geology.  
Ch. I.

#### *Progress of the Science.*

**THE** term Science, as now universally employed, is understood to express, not only the body of information collected, general laws established, or system recognised in any department of human knowledge, but also the ultimate objects and whole scope of the research. Strictly speaking, perhaps, the former is its legitimate meaning. Thus the Science of Optics or of Acoustics properly signifies the body of methodized information acquired in those branches of human study, but is popularly understood, by way of anticipation, to include indefinitely the expected or possible future accessions of knowledge on the subject.

It is in conformity with this ordinary language that we shall endeavour to give the definition of Geology; for though truly none of the Sciences of observation has made more remarkable progress toward successful generalization than this, yet the prospect of further discovery is so much richer than the retrospect, and the activity and talent employed in the research is so much on the increase, that we can hardly offer too bold and expanded an expression for the ultimate aims of Geology.

It might provoke a smile to recount the singularly contracted notions on this subject which have till lately figured in Works on Geology. The history of the Deluge, the discussion of the character and repositories of minerals, the classification of fossils, the causes and effects of volcanos, belong indeed to this comprehensive subject, but these and many more important inquiries, are only particular branches of the great study of Geology.

One reason of the inadequacy of the definitions usually presented, is probably not confined in its application to any one of the Sciences of observation, viz. the difficulty of foreseeing at the commencement of a new study, the direction and extent of its future development. Mathematical Science, founded upon the prevailing idea of relative magnitude, may by this comprehensive definition, anticipate all the various determinations concerning number, and proportion, and direction, which are daily added to its stores, and which are, in fact, the developments of recognised fundamental axioms; but the Natural Sciences have not this advantage, and it is only after they have made great progress, and many detached inferences, drawn from still more scattered data, have been combined into system, that the most able cultivators can clearly discern whereto their labours eventually tend.

**Definition.** Guided by these views, we shall define Geology as that Science to which it is allotted to investigate the ancient Natural History of the Earth; to determine by observation what phenomena of living beings or inorganic matter were formerly occasioned on or within the Globe, in what order and under what conditions; and from

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comparative data, furnished by investigation of the present operations of Nature, to infer the general system of successive revolutions which the Earth has undergone before arriving at its present state; and thus, finally, to furnish a complete view of the conditions which have regulated, and of those which do regulate, its system of mechanical, chemical, and vital phenomena.

From the terms of this definition we may at once understand why, in former times, the most able men erred so grievously in their attempts to elucidate the history of our Globe; for, while Geography was imperfectly known, before Commerce and the knowledge of Languages had made us acquainted with the productions and traditions of every clime, before the birth of most branches of Physical Science, it was impossible to accumulate the numerous and exact data from which alone Geology takes its origin. And since the general truths of Geology are made apparent only by the application of the known laws of Modern Nature, it is evident that, before the establishment of those laws, the wisest of the old Philosophers had nothing to substitute for enlightened theory but blind and fanciful conjectures. These are the reasons why the ancient doctrines concerning the World are almost without exception bewildered with the impossible problem of the Creation of Matter, and buried in a chaos of subtle inventions.

Cosmogony, not Geology, is the subject of the old traditions of Phœnicia, Chaldæa, Egypt, and China; and the same incurable fault vitiates the learned systems of Epicurus, Aristotle, and Pythagoras.

It is, however, interesting to observe a considerable refinement in the nature of the fictions by which those great men attempted to supply the want of fair deductions. The Epicurean doctrine of atoms, and the primary elements of Aristotle and Pythagoras, are favourably contrasted with the Egyptian egg of the World and the primeval monsters of Chaldæa. Familiarized with Countries in which frequent earthquakes and occasional volcanic eruptions necessarily accustomed the mind to a contemplation of great revolutions in Nature, we find both Aristotle and Pythagoras indulging the ideas of frequent changes in the relative extent of land and sea, and supporting this doctrine by reference to historical facts concerning subsidence and elevation of land, to the occurrence of marine shells far from the sea, and to the ordinary processes of Nature. But, in this respect, the Geographer Strabo appears to have far outstripped all his predecessors; for he distinctly alludes to the various explanations of the phenomena of marine remains, proposed by Eratosthenes, Xanthus, and Strato, and adds his own view of the matter, in terms not very different from those employed at the present day by the advocates of the gradual elevation of our solid land from the bed of the sea, as may be known by consulting the excellent review of Geological opinions given by Mr. Lyell.

The ten centuries of war and commotion which suc-

4 A

Geology  
Ch. I.

Speculative  
Geology.

Geology.  
Ch. I.

ceeded the destruction of the Western Empire, were less favourable to the growth of Physical Science than even those which had preceded; and while all the learning of the world was shut up in cloisters, and confined to one class of Society, we cannot wonder that the grand cosmogonies of the Ancients should have dwindled into puerile discussions. Learning was in chains, but it was nevertheless spread abroad through Christendom, and waited but for the extension of Geography and Commerce, by the maritime discovery of India and America, to be emancipated from its thralldom, and for the discovery of the Art of Printing to be excited to energy and enthusiasm, by the Physical and Astronomical discoveries of Kepler and Galileo.

It was not, indeed, till the Inductive Philosophy, budding in Galileo, blossoming in Bacon, and rich with fruit in Newton, had been widely disseminated among mankind, that we were entitled to look for fixed data and limited generalizations in any branch of Natural Science. The diffusion of this mode of philosophizing may be said to have withdrawn the veil of prejudice which had previously obscured the visible Creation, and to have really generated the Sciences which treat of the properties of Matter and the phenomena of Life.

Three different classes of phenomena have conducted men of observation to a partial acquaintance with the stratification of the crust of the Earth.

1. The arrangement of the various soils in England.
2. The appearances in the mines of Germany.
3. The remains of plants and animals entombed in the strata of England, France, and Italy.

The early advancement of Agriculture in a Country so populous, and of so diversified an aspect as England, necessarily produced a very intimate knowledge of different soils; and as these depend on the nature of the substances beneath, which range in regular courses, it is not surprising that maps of the soil should have been early proposed by agriculturists. Dr. Lister, residing in Yorkshire, where the ranges of soil are very well defined, was the first to propose to the Royal Society, in 1683, a Map of the soils of England.

"We shall be better able," he says, "to judge of the formation of the Earth, when we have duly examined it, as far as human art can possibly reach, beginning from the outside downwards. And for this purpose, it were advisable that a Soil or Mineral Map, as I may call it, were devised. The soil might either be coloured by a variety of lines or etchings: but great care must be taken very exactly to note on the Map where such and such soils are bounded. As for example, in Yorkshire, the woods, (wolds,) chalk, flint, and pyrites, &c. 2. *Blackmoor*, moors, sandstone, &c. 3. *Holderness*, boggy turf, clay, sand, &c. 4. *Western mountains*, moors, sandstone, coal, ironstone, clay, sand, &c. *Nottinghamshire*, mostly gravel, pebble, clay, sandstone, hall-plaster, or gypsum, &c. Now if it were noted how far these extended, and the limits of each soil appeared on a Map, something more might be comprehended from the whole and from every part, than I can possibly foresee, which would make such a labour very well worth the pains. For I am of opinion such upper soils, if natural, infallibly produce such under minerals, and for the most part in such order. But I leave this to the industry of future times."

This scheme was partly executed by the County Reports presented to the Board of Agriculture, the earliest of which dates from 1794; but the investigation being

usually unconnected with sound views of the interior conformation of the Earth, few of these detached efforts led to any important results. *Packe*, in his *Chorographical Chart of East Kent*, (1743,) has shown what admirable general views of the Physical Geography and leading rocks of a district may be entertained, without that combination of results which leads to Geology.

Miners in every period must have been acquainted with the order of succession of the rocks through which they seek the treasures of coal and metal; and in a tract consisting of alternating coal-seams, limestones, sandstones, and shales, as at Aldstone Moor, in Cumberland, the range and extent of the different strata must always have been familiar to the workmen.

There must therefore always have been a MINERALOGICAL SCHOOL OF GEOLOGY in every Country in which rich subterranean treasures attracted the attention of mankind.

*Agricola* embodied the floating information of the miners of Saxony, as early as 1546; (*De Naturâ Fossilium*;) and the appearance of five complete systems of Mineralogy in Sweden, and three in Germany, between 1730 and 1762, sufficiently proves the very general interest in the subject which prevailed in these great mining districts.

Those Works are principally devoted to a description of the most prominent Minerals, and it is only incidentally that we gain from them proofs of the considerable, though detached information which the authors really possessed concerning the manner in which minerals constitute, by their assemblage, the crust of the Earth.

In 1750, however, *Tylas*, a Swede, and in 1756, *Lehmann*, a German, broke through the fetters of a mere mineralogical method, and by proving a regular order of superposition among stratified rocks, opened the way to the sagacious generalizations of *Werner* and the cautious inductions of *Saussure*.

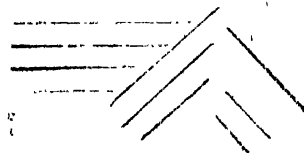
A peculiar set of opinions concerning the formation of the Earth, has been honoured by the title of the *Wernerian Theory*; and the pupils of *Werner* who had found proof of the truth of his practical inferences, may be readily pardoned for the determination which they have shown to uphold the hypothetical notions of their master. But if we wish to ascertain the real value of the benefits which the researches of *Werner* have conferred upon Geology, we must forget his Theory, and view only the data which he collected for its foundation.

*Werner* was educated amidst the mines, and in the society of the most eminent Mineralogists of Saxony; their experience and their opinions became his own, and doubtless swayed and directed the energies of his mind. To judge from his own Works, and from the course which his pupils have so long pursued, the principal point of view under which *Werner* contemplated the rocks and metallic veins of Germany, was the relative period of their production. *Lehmann* had, indeed, taken the same course, and already distinguished primary and secondary rocks,

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Origin of  
Inductive  
Geology.

Agriculture.

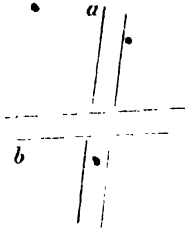


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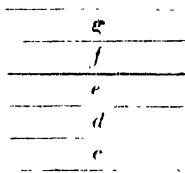
the former existing in mountain chains, mostly stratified at high angles of declination, and devoid of organic remains, the latter disposed more horizontally, and stored with the reliquæ of life. But Werner, with characteristic tact and boldness, applied this method of investigation to every case, and took it as the grand basis of his classification of rocks.

Basis of his  
system.

"When two veins (*a b*) cross, and one of them (*b*) cuts through the other, (*a*), the one which is divided (*a*) is the more ancient."



Among stratified rocks superimposed on one another, the lower members of the series, those which lie nearest the centre of the Earth, were deposited first, and the relative antiquity of the different strata is exactly in the order of their position. Thus *c* is the oldest rock of the series, *c*, *d*, *e*, *f*, *g*.



By this manner of proceeding in the instance of the Harz Mountains, Werner was enabled to frame a system or classification of rocks in the order of their respective position as far as could then be ascertained, and consequently in the order of their consecutive formation. Thus the Brocken Mountain was described by Werner and his followers as a central cone of granite, upon which on all sides round were laid various other rocks in a certain and constant order of succession; as granite, clay-slate, limestone, greywacke and greywacke-slate, old red sandstone, limestones, gypsums, sandstones and limestones; the upper and newer strata having their outgoing or terminal edges lower and lower continually.

Werner presumed that this order of succession among these rocks would be found to prevail in all parts of the World, and thus announced a grand principle in the construction of the Earth which was destined to have a most beneficial effect on Geological theory and observation. For, on the one hand, it dissipated the chaotic dreams of those who maintained that the whole crust of the Earth was to be viewed as a mass of sediment from the waters of "the Deluge;" and on the other, exhibited the most important subject of inquiry respecting the constitution of the Earth, and fixed a precise method of investigating it.

Extending his views through other parts of Germany, Werner completed the following system of successive formations. (*Jameson*.)

Werner's  
series of  
formations.

The lowest and oldest series of rocks discoverable by examination is supposed to be of crystalline origin, to be devoid of organic remains, and to have been ori-

ginally, as at present, stratified at high angles of inclination. These are called by Werner

*Primitive Rocks.*

Such are :

Granite,	Porphyry,
Gneiss,	Sienite,
Micaceous schistus,	Topaz rock,
Argillaceous schistus,	Quartz rock,
Primitive limestone,	Primitive flinty slate,
Primitive trap,	Primitive gypsum,
Serpentine,	Eurite, or whiststone.

A second series of rocks appearing to be partly of crystalline and partly of mechanical origin, containing some remains of plants and animals, with slopes of stratification less remarkable than the former, is named by Werner, on account of these intermediate characters,

*Transition Rocks.*

Transition limestone,	Greywacke,
Transition trap,	Transition flinty slate.

The third series consists of strata more decidedly of mechanical aggregation with abundance of organic exuviae, and from the greater frequency of these strata in the flatter regions of the Globe, where their planes of stratification are nearly level, they are called

*Flatz (flat-lying) Rocks.*

- 1st or old red sandstone.
- 1st flatz limestone.
- 1st flatz gypsum.
- 2d variegated sandstone.
- 2d flatz gypsum.
- 2d flatz limestone, or muschelkalkstein.
- 3d sandstone, or quadersandstein.
- 3d limestone, or planerkalkstein.
- Flatz trap.
- Independent coal formation.
- Newest flatz trap.

Lastly, various sandy and argillaceous strata, imperfectly known to Werner, but since ascertained to contain the whole vast series of tertiary strata, are included by him under the title of Alluvial Deposits.

That this classification is partly erroneous in principle, and in all respects incomplete and inadequate to the rigour of modern investigation, is apparent at a first glance, but it obviously contains the essence of all subsequent arrangements, viz. a determined reference to the antiquity of the deposit. Werner is, therefore, entitled to the distinguished praise of having established one of the most important general laws yet ascertained respecting the structure of the Earth. He has proved that its stratified rocks are laid one on another in a certain order of succession, which is the same, or very similar, over large parts of the Earth's surface. No one before Werner was able to perceive in any Country a regular system or series of strata, much less to imagine such a series to be universal.

It has been usual, especially in England, to quote a variety of persons before the date of Werner, to whom the honour of first declaring the principles developed by the Professor of Freyberg might with more justice be ascribed. The nature of his obligations to his own Countrymen has been already sufficiently stated. Mitchell, one of the most talented of the Natural Philosophers of England during the middle of the XVIIIth Century, who, for a short time, filled the Woodwardian Chair of Geology at Cambridge, and afterwards resided in Yorkshire, had certainly made himself acquainted with the series of English strata, especially in the Northern

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hurst.

Countries, and had even gone so far as to discover some of the most important general relations between the Geological structure and the Physical features of the Globe, defining with a masterly hand the mutual dependence of mountain ranges and lines of stratified rocks. The merit of Whitehurst, also, both as a theorist and as an observer, is very considerable. He states the object of his Work, published in 1792, to be "to trace appearances in Nature from causes truly existent; and to inquire after those laws by which the Creator chose to form the World; not those by which he might have formed it, had he so pleased." His mode of proceeding is exactly in conformity with the first clause of this sentence; for his whole Work is a finely woven web of plausible deduction and conjecture, founded on general Physical considerations, and supported or illustrated by a selection of corresponding facts and observations. This inverse process is certainly, in many respects, characteristic of a Cabinet Geologist; and yet this volume contains abundant proof, that its author was both well acquainted with a great variety of important data in Geology, and possessed of sufficient generalizations to develop their value. What is stated by Whitehurst concerning the succession of strata in Derbyshire and other parts, was chiefly derived from the miners and colliers, who, certainly, for a hundred years before the dawn of sound Geology, knew perfectly the almost invariable sequence of strata in their own districts.

\* Saussure.

The value of Saussure's distinguished services to clear the way for legitimate inductions in Geology cannot be better expressed than in the following passage of Cuvier, wherein he is compared with Werner

*En effet, la partie purement minérale du grand problème de la théorie de la Terre a été étudiée avec un soin admirable par De Saussure, et porter depuis à un développement étonnant par Werner et par les nombreux et savants élèves qu'il a formés.*

*Le premier de ces hommes célèbres, parcourant péniblement pendant vingt années les cantons les plus inacessibles, attaquant en quelque sorte les Alpes par toutes leur faces, par tous leurs défilés, nous a dévoilé tout le désordre des terrains primitifs, et a tracé plus nettement la limite qui les distingue des terrains secondaires. Le second, profitant des nombreuses excavations faites dans le pays qui possède les plus anciennes mines, a fixé les lois de succession des couches; il a montré leur ancienneté respective, et poursuivi chacune d'elles dans toutes ses métamorphoses. C'est de lui, et de lui seulement, que date la Géologie positive, en ce qui concerne la nature minérale des couches: mais ni Werner ni De Saussure n'ont donné à la détermination des espèces organiques fossiles dans chaque genre de couche, la rigueur devenue nécessaire, depuis que les animaux connus s'élèvent à un nombre si prodigieux.*

Inductive  
Geology  
principally  
founded on  
the dig-  
nic reli-  
quies.

The grand fact upon which, in all Ages, Geological inquiries have hinged, the occurrence of marine animals far from the sea and deep in the solid bosom of the Earth, was so far understood by the Ancients, that they had ascertained the general agreements of fossil and recent marine shells, nor does there appear the least trace of doubt on this subject in their writings. But warm discussions arose concerning them among the Naturalists of Italy, and at a later period, those of France, England, and Germany, Countries in which those exuvie are particularly plentiful and various.

The XVIIIth Century was wholly wasted in the ridi-

culous dispute whether the fossil shells were genuine marine exuvie, or mere *lusus nature* produced by a plastic power or fermenting fatty earth? and the question assumed a more difficult character from the addition of another, whether, if they were genuine petrifications, they were all deposited by the Noachian Deluge? In examining both of these points the Italian Philosophers were by far the most conspicuous, and it is difficult to understand how the sound conclusions of Steno and Scilla could fail to become the universal creed of Geology; yet long after Palissy in France had produced unanswerable evidence that fossil shells were the genuine exuvie of ancient marine animals, men voluntarily shut their prejudiced eyes to this most simple of all truths. The XVIIIth Century closed before the expiration of this absurd controversy; but as Truth infallibly gains strength by even the most unworthy contests, the strong interest attached to the solution of this problem spread universally among Naturalists the conviction that great discoveries concerning the structure of the Earth were to be accomplished, and the mode of contemplating its connection with Zoology received very capital improvements.

In England, especially, the superior interest which belonged to the thousands of fossil plants and animals, was fully understood by Llwyl, Ray, Lister, Woodward, and Moreton; who by their rich collections, and splendid publications, and resolute though unsuccessful efforts to deduce the causes which had thus buried and preserved imperishable in their everlasting tombs the organic remains of a former World, undoubtedly kindled that ardent spirit of inquiry respecting the structure of the Earth, for which the English Philosophers of the XVIIIth Century were so honourably distinguished.

Nevertheless, the progress of Geology in England was still retarded by the fettered condition of other Sciences, and by a peculiarly unhappy conjunction of Truth and Fiction. The correct view of the original nature of "formed stones, or petrifications," was coupled by Woodward and his numerous followers with the assertion, that all the strata superimposed on one another in the crust of the Earth, with all their included myriads of fossil animals and plants, were deposited by one general flood, "the Deluge!" This fatal error, the stumbling block of the Geologists of the XVIIIth Century, lay at the root of the brilliant hypotheses of Burnet, Woodward, and Whiston; and now, though discarded by every sound Geologist, it remains a serious impediment to the diffusion of correct general principles. One great merit, however, strikingly characterises the early English School of Geology, even in its greatest aberrations, a thorough conviction that the organic remains entombed in the Earth were the surest evidence of the revolutions which it had undergone.

In consequence, the whole island was filled with collections of fossils, which were compared with native and exotic living species, and almost every Naturalist of note from the time of Lister contributed something to the stock of information respecting them. That distinguished man, equally industrious and fortunate, and in general free from theoretical prejudice, had the glory of perceiving and of recording in a single instance the principle of mutual dependence between the strata and their organic remains, which afterwards, generalized and promulgated by Smith, became the most important instrument of investigation which has ever been presented to Geology.

Speaking of a small species of belemnites, (B. Lis-

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Fossiology  
in England.

Lister.

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teri,) which is figured in his *Historia Animalium Angliæ*, he says it is found in all the cliffs as you ascend the wolds, for above a hundred miles in compass, at Speeton, Londesbro' and Caistor, but always in a red, ferruginous earth. This correct and remarkable result is a striking example of the possibility of even holding in the hands a brilliant discovery, without knowing its value, or taking any steps to ascertain its importance.

Smith.

A century later, the perception of the same truth, in several instances near Bath, and the demonstration of its applicability to the whole secondary series of the strata of England, enabled Mr. Smith, by his own unaided efforts, to establish the Geology of England on a basis from which it can never be shaken; an accurate classification of the stratified rocks, in the order of their

relative antiquity, accompanied by Catalogues of their organic contents, and a Map of their ranges on the surface of the Island in conformity with the section of the interior.

The following Table, taken almost verbatim from Dr. Fitton's valuable notes on the History of English Geology, (*Phil. Mag.* 1832,) presents the list of English strata as published by Mr. Smith in 1815, and the corresponding arrangement at present admitted among Geologists; and thus at one view may be seen the entire distinctness of Mr. Smith's whole system of classification and method of naming, from that of any earlier continental writer; and the almost perfect exactness with which his views and names have been adopted by the modern School of English and European Geology.

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Smith, 1815.		1833.	
Characters of natural Districts formed by Groups of Strata	No.	Names of Strata on Mr. Smith's Map and Sections	Present Names.
(These beds above the chalk not noticed by Smith.)			
Plains	1	London clay	Crag of Suffolk.
	2	Clay or brick earth	Marine and freshwater strata of the Isle of Wight and Dorsetshire.
	3	Crag (this should have been placed first)	London clay.
	4	Sand and light loam	Plastic clay.
Chalk hills	5	Chalk { Upper, with flints Lower, without flints }	Sands above the chalk.
	6	Green sand	Chalk { Upper.
	7	Blue marl	Lower.
	8	Iron sand	Upper green sand.
		(The Wealden group not distinguished by Smith.)	Gault.
Clay vales	9	Portland rock	Lower green sand.
	10	Sand	Weald clay.
	11	Oaktree, or North-Walis clay.	Hastings sands.
			Parbeck limestone.
Stonebrash hills	12	Coral rag and pisolite	Portland oolite.
	13	Sand and sandstone, or calcareous grit	Sand.
	14	Dark blue, or Clunch clay	Kimmeridge clay.
	15	Kelloway stone	Upper calcareous grit.
	16	Cornbrash	Coralline, or Oxford oolite.
	17	Ilton sand and sandstone	Lower calcareous grit.
	18	Forest marble	Oxford clay.
	19	Clay	Kelloway stone.
	20	Great oolite	Cornbrash.
	21	Fuller's earth and rock	Sand and sandstone.
Marl vales	22	Under oolite	Forest marble.
	23	Sand	Bradford clay.
	24	Marlstone	Great oolite.
	25	Blue marl	Fuller's earth and rock.
Coal tract	26	Blue lias	Inferior oolite.
	27	White lias	Sand and grit.
	28	Red marl and gypsum	Upper lias clay.
	29	Magnesian limestone	Marlstone.
Mountainous	30	Soft sandstone	Lower lias clay.
	31	Mountain limestone	Blue lias.
	32	Red and dun stone	White lias.
	33	Various, killas or slate	Red marl and gypsum.
	34	Granite, sienite, and gneiss	Red sandstone.

To study the monuments of Nature according to the principles developed by Mr. Smith; to ascertain by the order of succession and by the organic remains what were the contemporaneous effects of the natural agents employed in the formation of the Earth in all parts of the World; is the great problem of modern Geology. By the aid of Zoological and Botanical researches we determine the relative antiquity of every species of fossil plant and animal, and assign the relative period during which its existence was continued. Orthoceras, trilobites, and many crinoides, belong to the

older and lower rocks; certain species of echini and shells mark the oolitic strata; while others belong to the chalk; and a series of plants, corals, shells, and vertebral remains, lies above the chalk, but is not found below. Such inferences, drawn from observations in Europe, have been found constant even in the New World: and if the powerful instrument of research thus placed in the hands of the observer, be wielded with the caution requisite in questions of analogy, the time is probably at hand when the principles disclosed by Mr. Smith's researches near Bath, and illustrated by Cuvier's philo-

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sophical description of the environs of Paris, will be found universally applicable; and the distant slopes of the Himalayah and the Andes, and the shores of Australia and Greenland, will be united in the mind of the Geologist who contemplates their coeval stratification.

Hypo-  
theses.

We shall here close our short account of the growth of Geology into a Science, without being tempted to indulge in the vain amusement of ridiculing those crude and visionary schemes which have too long been known by the misapplied title of Theories of the Earth. While the paths of observation, along which alone the foundations of the Science are to be sought, were hard and difficult, those of hypothesis were easy, flowery, and inviting. The globular figure of our Planet, the inequality of its surface, and the occurrence of marine shells in mountains far from the sea, have been thought sufficient data for rashness and speculation to construct detailed Theories of the Earth, to determine the constitution of its centre, and to describe, as if they had actually beheld them, the successive revolutions which it had undergone.

These unfortunate hypotheses were most numerous and discordant during the period when positive Geology had made the least progress; with the advancement of knowledge they diminished in number and improved in consistency, and at the present moment, though every professed Theory has lost its power of fettering the mind, there is a tacit but almost universal agreement in these fundamental principles of structure, and circumstances of origin, by which not only every passing Theory must be judged, but to which also all good observations and sound inductions must be referred. To develop these principles in a settled order, to illustrate by them and the Geological structure of the British Isles, and to connect the Geology of Britain with that of Europe and the terraqueous Globe at large, and thus to rise by a legitimate process to the most comprehensive inferences which the subject admits of, is the aim of the following pages.

We shall not, at the outset of our inquiry, prejudge the important questions which will arise for discussion, by deciding between Huttonian and Wernerian, or any other hypotheses; but allowing to their ingenious authors the merit of having really promoted Geology by stimulating curiosity and by directing inquiry, we shall for the present neglect them altogether, except so far as they may assist us to read well and interpret aright the rich and impartial volume of Nature.

Modern  
cultivators  
of English  
Geology.

But though Geology will not again own a master, its cultivators can never cease to be grateful to their ancient leaders; and many names connected with the general progress of English Geology in recent times, here demand the warmest expression of gratitude. The English system of Geology, based on the extensive labours of Smith, has been fully illustrated in Greenough's *Geological Map*, Buckland's *Reliquiæ Diluvianæ*, and Conybeare's *Geology of England and Wales*, a Work certainly not yet surpassed in merit, nor soon to be excelled unless by the continuation of it, which is anxiously expected, from the combined labours of Conybeare and Sedgwick. Scotland has been surveyed by Jameson and McCulloch, amply described by Boué, and put in relation with English Geology by the eminent researches on secondary rocks of Sedgwick and Murchison. Nearly the whole of Ireland has been ably treated by Weaver. The mineral condition of the British Islands has been to a great extent developed by

Sowerby, and the history of British fossil plants is in the hands of Lindley and Hutton. If from these comprehensive Works we should pass to those more local and definite discoveries which are the ultimate strongholds of the Science, many pages would not suffice to hold the praise so justly ascribed to De la Beche, Farey, Horner, Lonsdale, Lyell, Mantell, Miller, Webster, and other eminent names which will appear in the following descriptions. To the Geological Society of London, established in 1807, as a Body, belongs the high and enviable praise of unwearied and exciting activity, sound preference of permanent facts to transient Theories, invincible liberality of sentiment, and prophetic anticipation of that glorious expansion of the Science, which now claims for it the countenance and the active cooperation of every person interested in the interpretation of Nature, or concerned in the increase of the national wealth. Finally, there is yet a tribute to be offered to one whose ear is now dead to grateful praise, the man whose genius restored the vanished forms of Nature, and united the Zoology of all Ages of the World. What monument can be required for Cuvier, so long as the wonderful works of Creation claim the admiration of mankind?

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#### Materials in the Earth.

The first question which presents itself to the inquirer into the Natural History of the Earth is, what are the materials employed in its construction? To answer this question fully, and in all its extent, is now, and will, probably, for ever remain impossible, because with respect to the interior of the Globe we can learn nothing from direct observation, nor infer from Astronomical researches any thing more than that the materials, whatever they are which compose the more central parts, must have there a Specific Gravity, very much greater than that of the rocks which appear near the surface. The mean density of all the predominating rocks hitherto discovered is about twice and a half that of water; but the mean density of the whole terraqueous mass is four and a half times, or perhaps five times that of water. We may, therefore, safely conclude that the central portions are much heavier than the external crust; but beyond this all is speculation.

Mean density  
of the  
Earth.

It must not be concluded that because in the central parts the materials, whatever they are, have a Specific Gravity greater than those near the surface, they would also remain heavier if brought to the surface, for the compressibility of Matter under pressure would necessarily tend to the condensation of the internal nucleus of the Earth, and that in so high a degree, if the internal substances be of the same compressibility as those in the crust of the Earth, as to make the mean density of our Planet very much higher than it is known to be. Putting out of view the question of the Chemical relations of the internal substances of the Globe, and confining ourselves to Mechanical considerations alone, we should have, as conclusions of the greatest probability which the subject admits of:—

Specific  
Gravity of  
the materials.

First, that the superior density of the internal parts of the Globe is occasioned by the accumulated pressure which they have to sustain.

Secondly, that the effects of this pressure in condensing the internal parts of the Globe would be far more considerable than they are, were they not resisted within by some general antagonist force; such as the

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expansive power of heat, or an extraordinary want of compressibility among the particular substances operated on.

Thirdly, That the Earth's spheroidal figure has been attained in consequence of its having formerly been entirely fluid, during rotation on its axis, and is preserved because the internal arrangement of its materials, whether solid or fluid, is in equilibrio with the velocity of its rotatory movement.

Limitation  
of inquiry.

It cannot be too often nor too early impressed upon the mind of the student that Geology has no connexion with systems of Cosmogony. It is wholly a Science of observation and inferences, and limited to the phenomena presented within a small depth from the surface of the Earth. The regular disposition of the materials of our Planet does indeed permit us, in many cases, to infer, with the highest probability, what is the condition of its interior to a depth far beyond that actually visible to human eye; but still all the aids of Inductive Science are ineffectual to penetrate more than a few miles below the soil. It may, indeed, be the case, since the level from which volcanos arise is uncertain, that the materials which they vomit have been derived from greater depths, but the great improbability that these materials, after undergoing fusion, should be restored to their original condition, must make us hesitate to adopt volcanic products as evidence of the exact nature of the substances in the interior of the Earth. Our observations are, therefore, nearly confined to what is technically called the Crust of the Earth, and our legitimate inferences descend no lower than the rocks which appear in this crust.

Earthy  
compounds.

There is hardly any tract of country so limited as not to show a considerable diversity of earthy aggregates. Even in those districts which possess neither quarries, nor mines, nor cliffs, nor natural valleys, the surface of the land and the shores of the sea are generally strewed with fragments of different stones transported by some ancient powerful currents from regions in which Nature is more prolific, or more clearly reveals her treasures.

In the more level Countries the principal varieties of the earthy compounds or aggregates are included in the terms limestone, sandstone, and clay, of different colours, hardness, and fineness of grain. Each of these great divisions of rocks contains essentially a peculiar species of earth which imparts to the mass a particular derivative character. Thus,

LIME is the base of limestone,

SILICA of sandstone,

ALUMINE of clays.

MAGNESIA is an essential ingredient in certain limestones.

CARBON is the characteristic element of coal,

SODA of salt.

If we now turn our attention to the mountainous tracts, where crystallized minerals present themselves in an endless variety of combination; we shall, perhaps, be led to expect a corresponding abundance of primitive substances. But Chemistry has taught us that all this seeming inexhaustible variety is occasioned by a few earthy metals, and combustibles, and some of these are so rare, and even solitary in their occurrence, as to be of little importance in this inquiry.

By far the greater number of earthy minerals are composed of the same four substances, as limestones, sandstones, and clays, variously combined with alkalies and acids, and differently coloured by metallic oxides, &c. A good general knowledge of silicious, aluminous, cal-

careous, and magnesian minerals and rocks, is therefore the portion of Mineralogy most essential to a Geologist.

All the various aerial, liquid, and solid compounds which belong to this Globe are reducible to about fifty-four ingredients, which are termed simple or primitive, because, in the present state of Chemical Science, they appear incapable of further decomposition. Of these

Forty-three are *metallic bodies*, brilliant, electropositive, and, with the exception of potassium and sodium, heavier than water.

Of these thirteen produce, by union with oxygen, the Earth and alkalies,—

Aluminium,	Silicium,	Yttrium,
Glucinium,	Thorium,	Calcium,
Magnesium,	Zirconium,	Strontium
Barium,	Lithium,	Sodium,
		Potassium.

Five decompose water at a red heat,—

Manganese, Zinc, Iron, Tin, Cadmium.

Twenty-four do not decompose water at any heat. The more oxidable are,

Arsenic,	Antimony,	Copper,
Molybdena,	Uranium,	Tellurium,
Chrome,	Cerium,	Nickel,
Vanadium,	Cobalt,	Lead,
Tungsten,	Titanium,	Mercury,
Columbium,	Bismuth,	Osmium.

The less oxidable,—

Silver,	Rhodium,	Gold,
Palladium,	Platinum,	Iridium.

Eight non-metallic combustibles,—

Sulphur,	Iodine,	Carbon,
Phosphorus,	Bromines,	Fluorine?
Selenium,	Boron,	

Four gases,—

Hydrogen, Oxygen, Azote, Chlorine.

Every substance in this list is found in the mineral kingdom; and while the Chemist examines them separately in his closet, the Mineralogist studies their combinations in the field.

It may, perhaps, be imagined that innumerable combinations are derived from these fifty-four primary ingredients. But as many of them are excessively rare, as the remainder combine only upon certain principles, the number of mineral species really determined is, in fact, very small, perhaps hardly exceeding 300. Nor is the Geologist always called upon to make himself acquainted with all even of this moderate number. Unless his labours are devoted to the detailed phenomena of volcanic productions, or of mineral veins, he will seldom have occasion to observe more than one-tenth of the number. The reason of this is that a large portion consists of rare and local species, and that in combining to form rocks, the others are associated in families, and united into specific compounds without much permutation. Thus quartz, felspar, hornblende, chlorite, and mica, frequently occur together in granitic rocks, but other minerals, as calcareous spar, &c. scarcely ever accompany them. In consequence, then, of the rarity of many minerals, and the uniformity of the assemblage of others, there is really much less difficulty than might be expected in recognising and discriminating the rocks. To class and to describe them is difficult, to compare and to know them is easy.

Supposing, then, that the student has already made himself acquainted with the more common and remarkable rocks, as limestone, sandstone, and clay, various kinds of slates, basaltic, porphyritic, and granitic rocks,

Geology.  
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substances.

Minerals.

Geology. we shall now proceed to inquire in what manner they  
Ch. I. are arranged in the Earth.

### Stratification.

The best way of prosecuting this inquiry, is to begin at home, where precise information can be most easily acquired; next to compare our own with neighbouring districts; and, finally, extending our views over the whole surface of the Globe, to class the phenomena, and deduce the general results.

Arrange-  
ment of  
rocks on  
the surface.

It might be very excusable before Countries were cleared and cultivated, and before their various mineral productions were employed and understood, to imagine that the materials of the Earth were heaped together in confusion, the result of a chaotic formation; but at present, such a notion will not stand the test of a moment's reflection. One district has chalk beneath the surface, another limestone, a third coal, and a fourth granite, and these are never mixed or confounded together; so that the most careless observer must conclude that the different rocks are arranged after some ascertainable method. These different rocks are not mere insulated patches irregularly scattered through the country, but generally connected on the surface in long ranges, which in all the Eastern half of England have their prevailing direction from North-East to South-West. Thus the chalk of the Yorkshire Wolds is prolonged (see the Map of the British Isles) through Lincolnshire, Norfolk, Suffolk, Bedfordshire, Wiltshire, Dorsetshire, &c; the oolitic limestones range through Lincolnshire, Northamptonshire, Gloucestershire, and Somersetshire; and many other limestones and sandstones hold a parallel direction. Hence it happens, in proceeding from London toward the South-West, West, or North-West of England, we cross so great a variety of rocks, and so many ranges of hills.

A person proceeds from London to North-Wales. After passing low, gravelly plains in the drainage of the Thames, he climbs, by a long slope, the chalk-hills of Oxfordshire; crosses vales of clay and sandstone; ascends a range of oolitic limestone; traverses wide plains of blue and red marl; arrives in districts where coal, iron, and limestone abound; and, finally, sees Snowdon composed of slate. And if, in proceeding from London to the Cumberland Lakes, he finds the same succession of gravelly plains, chalk hills, clay vales, oolitic limestone ranges, blue and red clays, coal, iron, and limestone tracts, succeeded by the slate rocks, which compose the well-known summit of Skiddaw, will he not conclude that something beyond mere chance has brought together these rocks in such admirable harmony? Will he not have reason to conjecture that in the interior of the Earth regularity of structure must prevail?

Internal  
arrange-  
ment of  
rocks.

This conjecture becomes certainty when we explore the relative position of rocks as it is displayed in wells, pits, quarries, and mines, the works of human industry, or laid bare in cliffs and ravines by the hand of Nature. Here we see the rocks formed in layers or tabular masses of various thickness, but always of very great superficial breadth or extent and placed upon one another like the leaves of a book. These layers are called strata. Along the edges of hills, in the course of precipitous valleys, and by the margin of the sea, it not only is not difficult to recognise this truth, but it is almost impossible to avoid perceiving it.

Many parts of the English coast present what is

termed a natural section of the rocks, and accordingly whoever visits the shores of Northumberland, Yorkshire, Kent, Hampshire, Cornwall, South-Wales, or Cumberland, may easily satisfy himself of the stratification of most of the limestones, sandstones, clays, and slates of England. For most of the cliffs are composed of several distinct layers of rock, which are piled one upon another in a regular order, preserve a definite thickness, and appear under the same circumstances in many distant places. In the interior of the country the same conclusion is to be drawn from examining precipitous hills and deep valleys; and even in the flattest country, Art supplies the means of investigation which Nature has denied. The wells, and pits, and mines, which have been found necessary for the comfort of civilized Man, all display the same general truth, and lead us to conclude that the principle of stratification among rocks is confined to no particular Country; but whether in the New or the Old World, in Continents or in Islands, it is so remarkable and so constant, that colliers sink deep pits, and miners undertake extensive levels, in full confidence that no exception to its generality will affect the result of their enterprises. It is not a speculative truth, but a practical law of Nature, and is probably the fact of most extensive influence in the whole Theory of Geology.

So many important facts respecting stratified rocks flow in together upon the observing mind, that it is not easy to analyze them in the exact order of their occurrence. A person attentive to the subject cannot fail to discover, even in a very limited district, that the different strata which appear above one another, like the leaves of a book, are also, like them, arranged in a certain constant order of succession. A stratum which in any one situation is found beneath another will never, in any other situation, be found above it.

As a bookbinder sometimes neglects to bind in a particular leaf, so Nature sometimes omits a particular rock; but she never misplaces the rocks, as the careless workman sometimes misplaces his pages. Let us take, as an example, the cliffs on the coast of Yorkshire, between Flamborough Head and Robinhood's Bay. Gristhorpe Cliffs are crowned by calcareous sandstone rocks, which rest on a thick, bluish, argillaceous bed; under this is a brown, ferruginous sandstone, and, still lower, a thin, calcareous layer full of fossil shells. In Scarborough Castle Hill, the same calcareous sandstone, argillaceous bed, brown ferruginous rock, and fossil bed, occur in the very same order of succession. Or let us station ourselves at Leeds, and examine the coal pits of the neighbourhood. notice how many seams of coal are cut through, and what beds of sandstone and shale, and what layers of ironstone are met with. Then, inquiring of the workmen, we shall learn that the same "set of beds" is wrought at another pit. In this other pit we shall find the same beds of coal in the same order of succession, at nearly the same distances from one another, and of nearly the same qualities and thicknesses; and this strict analogy will be found at several pits over a considerable extent of ground, and, therefore, here, as well as on the coast, we obtain proof that in a limited district the strata are arranged with respect to one another in a certain constant order of succession.

Pursuing our investigation, we find that the strata are generally so disposed that their planes or broad surfaces are not exactly level or parallel to the Earth's spherical surface, but sloping in some one direction, so as, in that direction, to sink deeper and still deeper

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Super  
position  
of strata

Declina-  
tion of  
strata.

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into the Earth, and to be covered by other strata. This slope, this deviation from the horizontal position, is called the dip or declination of the strata; and the rocks are accordingly said to *dip* or *decline* to this or that part of the horizon. The different rocks which compose the interior to a considerable depth are, therefore, in consequence of this declination, exhibited in succession on the surface, and hence it is that mankind is furnished with a vast variety of mineral productions suitable to its numerous necessities.

Continuity  
of strata.

Any one thus far initiated in Geology, and possessed of common powers of observation, will be able to compose a list or scale of the strata which occur in his own neighbourhood, naming them in the exact order of their succession or superposition, and thus will be furnished with the means of comparing his own district with others near and distant. The results of this comparison are very important, for we thus learn that one general order of succession is observed among all the stratified rocks of England. Certain strata are locally deficient, but all those which do occur together are found invariably in the same relative position. The series of stratified rocks in the North of England, taken in a general way, is expressed by the following names: chalk, gault, Kimmeridge clay, coralline oolite and calcareous grit, Oxford clay and Hackness rock, cornbrash and Bath oolite rocks, lias shales, red marl and sandstone, magnesian limestone, coal system, mountain limestone, slate. The series in the Southern parts of England is precisely accordant, except that the magnesian limestone is there nearly deficient, and that the Kimmeridge clay is covered by some strata which do not pass the river Humber. Besides, we find the strata of the North of England actually connected by mutual extension with those of the same names in the South of England, so that we thus prove then *continuity over large tracts*, as well as the constancy of the order of their succession.

By means of these comparative observations, begun by Mr. Smith in 1790, and continued with unabated zeal by his numerous disciples, the whole series of English stratified rocks has been ascertained, and arranged in tabular order; and the Geologists of England have, in consequence, furnished to the rest of the world a standard of comparison, by which to determine how far the laws of stratification disclosed in this Island are applicable to other Countries.

Stratification a general principle.

Considerable labours remain to be accomplished before even the stratified rocks of Europe can be completely compared with those of England, and the want of evidence is still more severely felt with respect to the three other quarters of the Globe. Nevertheless, the following important general results may be regarded as certain. The principle of stratification is found to be *universal*; that is to say, in every Country of sufficient extent various rocks are found to be superimposed on one another in a certain settled order of succession, and these rocks are not found only in insulated patches, but often hold their course across Provinces and Kingdoms.

Throughout the whole area of Europe, from the Oural mountains to the Atlantic, and from Lapland to the Mediterranean, the stratified masses of the Earth, taken in their generalities, are arranged upon the same principles, follow one another in the same exact order of succession, and, in fact, form parts of one vast system of rocks, once more perfectly connected than at present.

What is known of the Geology of North Africa

Egypt, Syria, the Countries bordering on the Caspian, Siberia, and Hindustan, leads to a confident belief that the same general system, modified by local circumstances, will be found applicable to the greater portion of the surface of the Old Continent.

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Important agreements between the strata of North America and New Holland and those of Europe, have been already determined, and the time will probably at last arrive, when, if it cannot be proved, as Werner perhaps imagined, that similar rocks were at the same time deposited in every part of the bed of the ancient sea, at least it will be possible to show that the same system of natural processes was every where in progress, contemporaneously or successively producing analogous effects; and to ascertain the relative antiquity and accompanying circumstances of even the most distant deposits; and thus to exhibit, in chronological order, a history of all the varied yet harmonious operations, by which, in regular gradation, this Globe was filled with long-enduring monuments of the everlasting power and wisdom of its Creator, and made fit to be inhabited by a Being capable of interpreting the conditional effects, recognising the appointed agency, and venerating the universal Cause.

Analogy of distant deposits.

#### Distinction of Stratified and Unstratified Rocks

Stratification is, therefore, the most general condition, or mode of arrangement of the rocks which appear in the crust of the Earth; and in the wide plains and gently undulated portions of the surface, it is often the only one discoverable. A person of good discernment, who should pass his whole life in investigating the South-Eastern part of England, or the Northern part of France, might conclude, from every observation he could there make, that the external materials of the Earth were *universally* stratified.

On the other hand, the inhabitant of the mountains sees so many examples of granitic rocks, totally devoid of any appearance of stratification, and sometimes finds that structure in the slate rocks so dubious and inconclusive, that he is wholly unable to comprehend the magnificent chain of inductions derived from the study of stratified rocks. Unstratified rocks generally abound along mountain chains and groups, and very often form their axis or nucleus. Stratified rocks fill the plains, and form the encircling flanks of the mountains. When a vast mass of unstratified rock, as granite, forms the nucleus of a mountain group, the stratified materials which surround it, generally slope away on all sides, as if the granite had been protruded from below the strata, and, during the act of its uplifting, had broken them, and caused them to assume their several inclinations. Other unstratified rocks, as basalt and porphyry, appear amongst the stratified rocks, sometimes in irregularly lenticular masses, as if they had been spread in a melted state around a common centre, sometimes filling long vertical fissures in the strata, as if they had been injected from below.

On comparing together the stratified and unstratified Mineral rocks, we find their mineralogical composition extremely different. The *stratified rocks* are earthy aggregates, as sandstones, clays, or simple Chemical precipitates, as limestone; such materials, in fact, as we know to be accumulated in the same mode of arrangement by modern waters.

The *unstratified rocks*, on the other hand, are gene-

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rally and evidently crystallized masses, often analogous to volcanic products, or compounds containing essentially minerals which are not known to be producible from water, but in several instances are obtainable by artificial heat, or generated in the deep furnaces of which volcanic mountains are the vents.

Stratified rocks have evidently been deposited successively from above; the lowest first, the uppermost last, in obedience to the laws of Gravity.

Unstratified rocks, on the other hand, seem to be derived from the depths of the Earth, and to have been ejected or uplifted from below the strata, as volcanic matter is protruded at the present day.

Contents.

Stratified rocks contain very generally the remains of the plants and animals which were in existence at the period of their formation, exactly as remains of the present races of plants and animals are found buried in the modern deposits of water.

But unstratified rocks contain no such evidences of watery origin or mechanical aggregation.

Origin.

By all these characters, separately and comparatively considered, the two great divisions of materials which compose the external parts of our Globe, are proved to have been produced by entirely opposite causes. STRATIFIED ROCKS are analogous to the modern PRODUCTS OF WATER, and are therefore called Neptunian, while UNSTRATIFIED ROCKS are analogous to the modern PRODUCTS OF SUBTERRANEAN FIRE, and receive the names of Plutonic and Volcanic, according to the degree and circumstances of this analogy.

Mode of study.

The distinction now insisted upon, between the Neptunian and Plutonic formations, between stratified and crystallized rocks, is of the highest importance, and deserves the first notice, even on the very opening of the subject of Geology. For not only are these different classes of rocks distinguished by most important general characters, but even the methods by which they are to be investigated, and the preliminary knowledge required for this purpose are entirely distinct. Amongst the stratified rocks a knowledge of Zoology and Botany is required to develop the past history of innumerable remains of plants and animals, which were buried at successive periods, on the contrary, among the mountains associated with granite, where minerals of every hue and form appear in every different combination, scientific Mineralogy is of much higher importance.

In consequence, Geology divides itself into two branches, one of which links itself with the Natural History of modern plants and animals; and the other with Chemistry and Mathematics. And we have now, and have always had two distinct groups of Geologists, whose progress and discoveries have been as different as the preliminary knowledge which their different spheres of research required.

A Geologist of adequate attainments must indeed be supposed acquainted, at least generally, with both branches of this magnificent subject, and therefore a person entirely ignorant either of Mineralogy, on the one hand, or of Zoology and Botany on the other, must be considered as only half-educated. He may, indeed, be a very useful local observer, but he must be further instructed in his Science before he can be sent to explore an unknown region, or permitted to give an opinion on the whole Theory of Geology.


As much knowledge, therefore, as can be easily gained of the minerals which enter most frequently into the composition of rocks and veins, and of the Natural History of

the plants and animals whose remains lie buried in the strata, is absolutely necessary to every professed Geologist. Yet on this account the student ought by no means to be discouraged; for this preliminary knowledge will be quickly, though insensibly, acquired by an intelligent observer, in exact proportion to his need of it. In a level country composed of limestone, sandstone, and clay, the multitudes of organic remains which continually meet his eye will infallibly procure him the power of discriminating their specific forms; and among the mountains associated with crystalline granite, the endless repetition of the objects will generate a Mineralogical tact in the eye, and a Mechanical if not Mathematical notion of the structure of crystals.

The summary observations which will be introduced in this Treatise on the preliminary Sciences of Zoology, Botany, and Mineralogy, will be placed with those divisions of the subject to which they respectively belong, and where they will be the most intelligible as well as the most useful.

#### On Stratification in general.

*Strata, layers, and beds, are synonymous terms.* "Strata," says Professor Playfair, "can only be formed by seams which are parallel throughout the entire mass." This definition, founded upon the supposition that loose materials deposited under water must be arranged in layers parallel to the surface of the water, undoubtedly contains the general or fundamental idea of stratification, but is often too abstract for practice. The most remarkably regular and parallel seams or divisions between the strata happen in calcareous and argillaceous rocks; but the partings in sandstone are much less uniform. A particular shelly bed of stone lies at the top of the coralline oolite of Yorkshire, and may be traced for a great distance; a red band, long since noticed by Lister, lies at the base of the chalk of Yorkshire and Lincolnshire for sixty miles in compass; the cornbrash limestone, seldom more than ten feet in thickness, is continuous from Dorsetshire nearly to the Humber. In these instances, therefore, Playfair's definition applies very well; on the contrary, the beds of sandstone with coal which are interposed in the oolitic system of Yorkshire, are altogether 500 feet thick near Robin Hood's Bay, but dwindle toward the South, and are entirely deficient before reaching the Derwent.

Such beds are therefore wedge-shaped  and cases sometimes occur where, by attenuation in all directions from the centre, they become lenticular. See pl. 1. fig. 1. for these and other appearances.

The strata, therefore, are not all coextensive. Lime-Interposed stones are probably the most persistent and regular, strata. sandstones the most limited and local. Local or interposed beds cause the principal differences between distant portions of the same formation.

The bas of England rests immediately upon red and bluish marly clays with white gypsum: at Luxemburg, they are separated by a thick sandstone. In the North of England, magnesian limestone separates the coal from the upper red sandstone; but in other parts of the Island these two formations are in contact. In the breast of Ingleborough, the limestone beds are aggregated into one vast mural precipice or scar; but as we proceed Northwards this mass opens to admit layers of sandstone, shale, and coal, which gradually increase under Crossfell, and swell out to a vast thickness in Northumberland, so as to contain several valuable seams

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of coal, thick rocks of sandstone, and abundance of shale, between the horizontally separated beds of limestone.

The oolitic strata near Bath are composed of two portions, the upper or great oolite and the lower oolite, and between them is a series of calcareous and argillaceous beds called fullers' earth beds, sometimes 150 feet thick. As we proceed Northward into Lincolnshire, the fullers' earth beds are excluded from the series; still further North the whole series is changed; so that in Yorkshire it includes thick layers of sandstone, shale, and coal. On a first view the districts of Bath and Yorkshire are very unlike, but the contemporaneity of their disposition is certain from the continuance of the same oolitic beds through both of them.

thickness

The *thickness* of the beds or strata varies exceedingly and seems to have reference to the rapidity, regularity, and continuity of the deposition and the rate of drying or consolidation of the materials.

The chalk rock is about 500 feet thick, and in all this great mass we can scarcely trace any decided beds; though the layers of flint at equal distances, (four to eight feet,) and the difference of the organic remains at different depths, evidently prove a succession of stratified deposits.

The great oolite near Bath is on the contrary divided into a *certain number* of beds, definite in quality, thickness, and order of position.

nature

A certain stratified rock, therefore, is composed of one or more layers or strata, but this is by no means the last term of the analysis. Each bed is often composed of many laminae which are sometimes parallel to the plane of the bed itself, and sometimes lie in it at different angles. Thus micaceous laminated sandstones, and in particular the best flagstones of the coal districts, are composed of a multitude of thin layers parallel to the plane of the bed, and entirely covered by plates of mica which probably cause the splitting of the stone. This appearance is very analogous to the laminated sand quietly left by the successive floods of a river.

But the coarser flagstones of the same coal districts are often composed of laminae, laid at various angles to the plane of the bed, and in consequence producing a rough, uneven, shattery surface, and a tendency to oblique fractures; thus, in pl. i. fig. 2. *a* represents the regular, and *b* the coarse irregular flagstones.

Such appearances of oblique lamination are occasionally found in the modern sediment of agitated waters, both in the banks of rivers and on the sea-shore.

When these oblique laminae extend through thick beds, they sometimes cause a slight difficulty in determining the dip of the strata, and are then called *false bedding*. Some of the coarse upper beds of the great oolite of Bath, Gloucestershire, Northamptonshire, and Lincolnshire, as well as of Normandy, are remarkable for this false bedding.

But it is in the coarse sandstones that we see the most remarkable examples of this structure, as on the Scarborough coast and under Nottingham castle.

The more violent the action of water, the less regular is the internal constitution of the layers found beneath it. Let any one with this view compare the effects of the tide beating upon the sand and pebbles of the Eastern coast, or the tumultuous products of a mountain river, with the tranquil deposit and sediment on the alluvial lands near Lynn and near Hull. In the former case, the materials are frequently found heaped together in laminae, variously and confusedly inclined to one another; in the latter they are all parallel to the horizon,

and to the general plane of the surface. The former case is exactly analogous to the false-bedding mentioned in a preceding section, so general in our sandstone conglomerates, and in shelly beds of oolite; the latter is exactly like the regular lamination of clays and shales. Like effects flow from like causes, and thus we are enabled to frame very plausible conjectures concerning the condition of the waters under which the several strata were accumulated.

In the same way as a number of similar laminae are sometimes united into one bed of stone, so several similar beds of stone, are sometimes associated into one rock, to which a specific name is applied, as the OOLITE, the LIAS LIMESTONE, &c.

Sometimes several of these rocks are grouped under the title formation, as the BATH OOLITE FORMATION. Thus in the lias limestone-beds, the lower lias clay, marlstone-beds, and upper lias clay, as represented in pl. i. fig. 3. are all included in the LIAS FORMATION, which rests upon the RED SANDSTONE FORMATION, and is covered by the BATH OOLITE FORMATIONS.

The following Table exhibits a complete view of the whole series of British strata, grouped according to their relative antiquity into three leading divisions, the Primary, Secondary, and Tertiary strata; it being understood that such divisions are chiefly adopted for convenience, as expressing with considerable accuracy certain general analogies of origin, composition, and organic contents, which prevail amongst the members of each division, but yet are not to be considered as exclusively belonging to them.

Two of these divisions are again subdivided upon exactly the same principles into systems of strata, which are marked by certain recurrent rocks, striking analogies of composition, organic reliquiae of similar types, and positions derived from convulsions of the same epoch.

The systems are again usefully divided into formations; these into their several component rocks; whose ultimate analysis gives the strata, beds, and laminae of composition. The superficial accumulations of gravel, sand, peat, &c., which are classed under the head of diluvial and alluvial deposits, are not included in this list of strata.

For the sake of the student to whom the mode of considering the sequence of rocks may not be familiar, the strata are here placed in the same order as they would be found on proceeding from the surface downward. This Table should be compared with that of Mr. Smith, p. 533, and of Werner, p. 531.

## TERTIARY SERIES OF STRATA.

partly lacustrine, but principally marine, sandy, and argillaceous, and with some calcareous deposits, abounding in shells and other organic exuviae, closely analogous to existing species.

Formations.	Usual thickness of Formation, feet	Stratified Groups.
1. Upper marine formation .	50 . . . . .	{ Sandy crag with shells. Zoophytic limestone. Upper freshwater limestone and marls
2. Mammolacustrine . . . . .	100 . . . . .	{ Intermediate marine bed. Lower freshwater limestone and marls.
3. Lower marine formation .	1000 or more.	{ London clay group. { Bagshot sand. { London clay. { Plastic clay group. { Plastic clay, with coloured sands and lignites. { Shelly blue clays and sands. { Pebbly green sands.

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## SECONDARY SERIES OF STRATA,

principally of marine origin, with rare and local estuary deposits; consisting of repeated alternations of limestone, flint, sandstone, sand, clay, iron ores, coals, salt, &c., with organic remains generally very distinct from existing forms of animals and plants.

*Cretaceous System.*

Formation.	Thickness. Feet.	Stratified Groups.
4. Chalk, . . . . .	600 . . . . .	{ Upper soft chalk with flints. Middle harder chalk Lower marly chalk Red chalk
5. Green sand, . . . . .	500 . . . . .	{ Green and grey sands. Gault clay. Iron sand or lower green sand.

*Oolitic System.*

6. Wealden, . . . . .	. . . . .	{ Weald clay and Sussex marble. Hastings sands and limestones. Purbeck limestones and clays. Portland oolite and other limestones
7. Upper oolite, . . . . .	400 . . . . .	{ Kimmeridge clay. Upper calcareous grit. Coralline oolite. Lower calcareous grit. Oxford clay. Kelloway calcareous grit rock. Clay.
8. Middle oolite		{ Coralline oolite group. Oxford clay group.
9. Lower oolite, . . . . .	. . . . .	{ Cornbrash limestone. Forest marble and sands. Great oolite. Fullers' earth, rock, and clays. Inferior oolite. Ferruginous sand. Upper has clay, or shale. Marlstone beds, sandy and calcareous
10. Lias, . . . . .	. . . . .	{ Lower has clay, or shale. Lias limestone Dark marl

*Siliceous System.*

11. Variegated sandstone (Peculiar, Conybeare.)		{ Variegated marls, gypsum, and salt. Red and white sandstone. Red sandstone conglomerate. Red and white marls. Laminated limestone.
12. Magnesian limestone		{ Gypseous red and white marls. Magnesian limestone. Marl shale. Rothetodteliegende.

*Carboniferous System.*

13. Coal, . . . . .	. . . . .	{ Alternating Sandstones. Shales. Coals. Ironstones, &c. resting on Millstone grit.
14. Mountain limestone		{ Alternating Limestones. Shales. Gritstones. Seams of coal. Conglomerates.
15. Old red sandstone		{ Flagstones. Red and white marls.

## PRIMARY STRATA,

containing organic remains, mostly of extinct tribes, and only in the upper part of the series.

Slate system, including many great divisions which eventually may be classed in formations, according to their organic remains and bands of limestone. It is a

usual, but vague classification, to distinguish this system into upper or fossiliferous, and lower, or non-fossiliferous slates and limestones. Gneiss and mica schist system, including mica schist, chlorite schist, hornblende schist, quartz rock, primary limestone, gneiss, &c.

Granitic rocks, which are not stratified, usually form the basis of the strata, and are frequently but not by any means universally followed by the gneiss and mica slate system.

*Disturbed Stratification.*

All strata, says Cuvier, in his admirable "Discourse on the Revolutions of the Globe," must necessarily have been formed horizontal; and this opinion, founded upon the admission that rocks composed of regular layers, containing rounded pebbles, and organic remains of watery animals, can only have been formed under water, is supported by observation. For not only do we see at the present day the deposits of water arranged in planes nearly or exactly horizontal, but we also find the ancient strata of the Earth, where undisturbed by convulsions, very nearly level. In consequence of these disturbances the strata are seldom found to be perfectly horizontal, but are often inclined at high angles, and in a few instances stand directly vertical. Their planes are generally continuous over large spaces, but they are sometimes broken and dislocated by faults or dykes. It is now generally admitted that the usual horizontal disposition of the strata is derived from the action of the supernatant waters which accumulated them; and that the irregular declinations and fractures which we sometimes behold, are the effects of subterranean convulsions, chiefly occasioned by internal expansion. The truth of these opinions will appear from a few plain considerations.

Earthy matter deposited from water by tranquil subsidence, as clay and limestone, or accumulated during periods of moderate agitation, as sand and sandstone, must in general be accumulated into layers or strata, proportioned to the intervals of deposition; and these layers, in consequence of the fluctuation of the water and the influence of gravitation, will especially tend to be horizontal. Nevertheless they must, in a considerable degree, accommodate themselves to the surface on which they are deposited. If the bottom be level, so will be the deposit; if sloping, the deposit will be inclined; but if there be a perpendicular subaqueous cliff, no deposit can fall upon its face, nor any transported materials be accumulated parallel to it. An originally perpendicular layer or deposit of earthy materials is obviously impossible. Whenever, therefore, we behold vertical strata, we may be quite sure that they were not deposited in that form, but have been displaced by some internal movements of the Earth. Abundance of instances of this remarkable position of strata may be quoted in almost any part of the World. The Isle of Wight gives us a magnificent series of strata 1100 feet in thickness, reared into an absolutely vertical position; and this effect is the more remarkable, because the materials uplifted consist of many strata of loose sands and pebbles which most certainly have been deposited level. In the Western border of Yorkshire, vertical strata of limestone range for miles parallel to the edge of the Pennine chain, and turn Eastward through Craven, below Ingleborough and Penygant to Settle. Magnificent examples of vertical strata are familiar to those who have visited the cliffs of Savoy, or who have perused the graphic descriptions of Saussure.

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Ch. I.Contorted  
strata.

There are some remarkable instances of contorted stratification very difficult to be explained without supposing the strata to have been soft at the time of the flexure. Not to dwell on inferior examples, we shall quote the magnificent phenomena of this kind which are seen in the valleys of Chzmouni and Lauterbrun, and along the shores of the Lake of Lucerne, near Fluellen. The stratified limestones of these localities are bent into such extraordinary retroflexions, as to imply repeated operations of the most violent Mechanical agency, in different directions; and observations along the range of the Alps prove that the whole of this chain has been the theatre of enormous and reiterated concussions. (pl. i. fig. 4.)

Faults.

But the most remarkable case of disturbance is when strata, either horizontal or inclined, are broken, so that on one side of the line of fracture the rocks are much higher than on the other. This difference of level sometimes amounts to 100 or even 200 yards. The succession of strata is on each side the same, their thickness and qualities are the same, and it seems impossible to doubt that they were once connected in continuous planes and have been forcibly and violently broken asunder.

The plane of separation between the elevated and depressed portions of the strata is sometimes vertical, but generally sloping a little. In this case a peculiar general relation is observed between the inclination of this plane and the effect of the dislocation. In the diagram, (pl. i. fig. 5.) for instance, the plane of separation,  $z z$ , slopes under the depressed, and over the elevated portions of the disrupted strata, making the alternate outer angles  $z z b$ ,  $z' z' b'$  acute. In more than a hundred examples of such dislocations which have come under the notice of the writer of this Essay, he never found an exception to this rule. A similar law is found to prevail very generally in the crossing of nearly vertical mineral veins; for instance, (pl. i. fig. 6.)  $a g$  are two portions of a metallic vein dislocated by another vein,  $b b$ . In this case the relation of the line  $b b$  to the lines  $a a$ , is the same as that of  $z z$  to the lines  $a a$ ,  $b b$ ,  $c c$ , &c. The contrary appearances, had they occurred, would have been as represented below; and such occur in the mining district of Cornwall together with many other singular phenomena, apparently referable to subterranean disturbance, perhaps complicated with other causes, but which are with difficulty reducible to any simple mode of explanation.

The line of dislocation is generally distinguished by a fissure, which is filled by fragments of the neighbouring rocks, or by basalt, and is then called a *dyke*; or by various sparry and metallic minerals, and is then called a *mineral vein*.

Relative  
age of the  
dislocation.

The irregular operations by which these disturbances and dislocations were occasioned, seem to have happened at various periods during the formation of the strata. We know, for instance, examples of horizontal strata, as  $a b$  (pl. i. fig. 7.) resting upon highly inclined strata,  $x y z$ , which must have been forced into their unnatural position before the deposit of the level strata upon them.

Such a case occurs in Somersetshire, where the coal measures lie at a steep slope beneath horizontal beds of red marl. These coal measures are also greatly broken by faults which in some cases throw or elevate the beds on one side more than seventy fathoms above those on the other side. But the beds of red marl above are altogether uninfluenced either by the steepness of the dip

or the abruptness of the dislocations. Therefore the convulsions by which these effects were occasioned, happened after the deposit of the coal seams, and before the deposit of the red marl.

At Aberford in Yorkshire, and at many other points along the line of the magnesian limestone between Nottingham and Sunderland, similar examples occur.

In such cases the discordance of inclination between the superior and inferior strata is expressed by the term *unconformity*, and the rock is said to lie *unconformably* upon the lower.

By pursuing this investigation in different situations, we find that these internal movements or convulsions happened at intervals during the whole period of time occupied in the deposition of the strata. The most prevalent and remarkable cases of dislocation and unconformity are however observable: 1. immediately after the deposition of the slate series; (*Transition series* of Werner;) 2. after the accumulation of the coal system; 3. after the deposition of the oolitic rocks; 4. after the deposition of the chalk; and 5thly, one of the most recent probably of all, after the completion of almost all the formations above the chalk. It is not to be supposed that all even of these principal cases of dislocation can be recognised in every Country; on the contrary, the subterranean forces appear frequently to have shifted their points of action.

We shall have occasion to show, while speaking of the organic remains, that there is sometimes observed a singular harmony between these periods of extraordinary internal disturbance and the several epochs when the different races of animals and plants came into existence; and it is not unreasonable to suppose, that in this manner it may be hereafter found possible to establish such a relation between the internal and external condition of the Earth, as to afford the greatest assistance towards defining the agencies which have produced changes so extensive and repeated in both.

At present, restricting ourselves to the phenomena of elevation and disruption of the strata, we shall carry our inductions one step further for the purpose of proving what was before announced, viz. that these disturbances were connected with the effects of internal fires.

We shall assume then that granitic, and basaltic or trappean rocks, and others exhibiting the same phenomena, were crystallized from a state of igneous fusion, and were, sometimes in a fluid and sometimes in a solid state, impelled upwards from the interior of the Earth, as analogous substances are now raised fluid through volcanos, or hited solid by earthquakes.

In proportion as we approach the mountains where the greatest violence was exerted to break up the strata, raise the granite, and inject the basaltic dykes, we find the dislocations increased in number and importance, and the confusion of the stratification more prevalent.

The central nucleus or axis of many mountain districts is a mass, or a series of masses of granite and other unstratified rocks, from which on all hands the strata are found dipping at high angles. In such cases there can be little room to doubt that the elevation of the mountain ranges and the disturbance of the strata, was occasioned by the same violence which uplifted the granite. See pl. i. fig. 8.

The area of granite disclosed between the opposite slopes of slate, is indefinite, sometimes very large,

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sometimes very small, sometimes it is entirely covered over by the slate, which it has uplifted, but not perforated. The general analogy in the composition of mountains, in the strata which surround them, and in the dislocations which abound in their vicinity, prove that one common cause, the force of subterranean fire, has produced all the phenomena in question.

Basaltic rocks frequently, perhaps generally, show themselves in situations removed from the granitic regions, on the flanks of mountains and in lower ground. In numerous instances, basalt fills up the fissure between the elevated and depressed portions of dislocated strata, and as it cannot be doubted that such a fissure would soon have been filled up by other substances, it is clear that the melted basalt was injected nearly at the same time as the dislocation was produced; that is, that both were local effects of violent internal heat.

Analogy of  
mineral  
veins and  
trap dykes.

So great a general analogy prevails between some mineral veins and basaltic dykes, that in almost all hypotheses their origin has been assumed to be the same. Both in the same manner divide the strata; in both the materials are crystalline, generally such as are not known to be producible from water, and arranged according to entirely different laws from those which regulate deposits from water. It seems besides almost inconceivable that materials of such various Specific Gravity and Chemical affinities should be either soluble at once in water or capable of being introduced by this process at different times; on the contrary, all the circumstances agree in claiming for such mineral veins the same origin as basaltic dykes, the igneous origin of which is supported by the strongest possible arguments. We shall, however, discuss the history and origin of mineral veins more at large in the Chapter on Plutonic Products, and we shall then notice a variety of phenomena concerning them which can with difficulty be explained in the present state of our knowledge of Chemistry. That part of the history of mineral veins and metallic substances in general, which is inseparable from the consideration of the rocks in which they occur, will be treated of while speaking of the several strata in succession.

Disruptions  
of strata,  
a part of  
the general  
plan of ter-  
restrial  
adaptations

This elementary statement of the characteristic effects of subterranean convulsions upon the preconsolidated strata, must not be closed without noticing an important beneficial result of them upon the condition of mankind. The frequent use of the terms convulsions, dislocations, and other such phrases in Geological Treatises, may, perhaps, lead the inattentive reader to imagine that Geologists are of opinion that the laminated crust of the Earth, which had been constructed with so great harmony and order, was afterwards subjected to accidental injury, left to the violence of forces not contemplated in its formation, and the original plan of its fabric destroyed by unforeseen convulsions. How false a notion is this, and how unjustly would Geologists be accused of ignorance in this respect! They know well that without the effects, which are called convulsions and dislocations, the plan of the terrestrial creation would have been incomplete, the Earth not adapted, as it is, for the residence of men and the exercise of human intellect, which in all this seeming confusion can discern the progress of an uninterrupted plan, and even trace special provisions in favour of mankind. Whether we regard the mere animal nature of Man, or consider him with reference to those glorious endowments which lift him above the brute, and enable him to contemplate the past and anticipate the future, and thus to expand

his intellectual existence through all periods and over all subjects, we shall find in the broken stratification of the Earth, the most remarkable attention to his Physical and Mental constitution.

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Elevation  
of conti-  
nents.

How universal are the benefits which are conferred on Commerce and the Arts of life, by the variety of substances obtained from the Animal Kingdom, cannot require to be stated; for without this variety, neither Commerce nor the Arts of life could exist. Some faint idea of the state of a Globe which did not show this variety, may be conceived by viewing the condition of the sandy deserts of Africa, and abstracting from their solitary desolation the assistance rendered by more favourably situated Countries. Now all that variety of mineral products existing in the Earth, stored up in that inexhaustible repository to supply many regions through many national revolutions, would have been made in vain, and for ever hidden from the eyes of men, but for these very convulsions and dislocations in the strata. What else has raised our mountains, divided our seas, and given currents to our rivers, and by so doing established upon the Globe those varieties of soil, local climate, and other conditions to which the organic wonders of Creation are most evidently adapted? What other means have been employed to produce the natural, harmonious, and mutually dependent relation of plants and animals on the land, in the streams, and in the sea? Without these disruptions, the Earth would still have been uniformly covered by shallow waters; or if some part rose above it, must have been a barren waste, or a monotonous surface on which the living wonders of Nature, according to the actual plan of Creation, could not have appeared. It is, therefore, evident, that as one of the means employed by the Creator in the accomplishment of his works, the agency concerned in producing the actual condition of the terraqueous surface, and thereby regulating the leading phenomena of organic and inorganic Nature, is a fit object for the special study of Geologists.

It is not only in the elevation of continents, the varying height of mountains, the division of the sea, and similar striking effects, that we see the utility of the combination of subterranean igneous with superficial aqueous agency. Every coal-field in the known World proves distinctly the utility of even the minor dislocations, which in our imperfect language are called "faults" in the strata. The universal effect of these "faults" is to multiply the visible edges of the strata, by bringing them more frequently to the surface, in consequence of which there is, in the first place, the greater chance of discovering the materials of the Earth; and, secondly, the greater facility of working them. Other advantages of this kind will immediately suggest themselves to the attentive reader.

Exhibition  
of useful  
minerals.

But all advantages to Commerce and the Arts of life sink into nothing when compared with the effect which the Human Mind experiences from contemplating the monuments of past conditions of the Globe, which the uplifting of the bed of the sea, and the dislocations of the strata, have brought to light. All Nature is a glorious book, which men are incited to read, in order to know and communicate with its Author, a mirror in which the Almighty and the Infinite is faintly typified in the vast and the diversified; and in this respect, Geological monuments are distinct, impressive, and, in reference to the earlier epochs, unique. But, if we have been conducted by long labours to some real knowledge of the internal constitution of the Globe

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and familiarized with the conception of many revolutions of created Beings on its surface, in accordance with a long sequence of Mechanical and Chemical operations; and if we have thus extended the conviction of the unceasing care and comprehensive benevolence of the Divine Being to the most remote epoch which our limited intellect can reach; all this is owing, in a certain sense, to the convulsive movements originating below the crust of the Earth. Let it not, therefore, be supposed, that, because of the contracted scale of the Human Mind, which can see only in succession what to a greater Intelligence is contemporaneously evident, Geologists are obliged to speak of certain phenomena as *accidents* with reference to others, which are connected therewith by ways unknown to us, that they are so blind as not to see in all the diversified operations of Nature, the effects of One predisposing and directing Cause.

### Internal Structure of Rocks.

joints in  
different  
rocks

All rocks, whether stratified or not, are naturally divided by fissures, passing in various directions, independent of the strata, into masses, which are of different form in dissimilar rocks, and are accompanied by circumstances deserving more attention than has yet been bestowed upon them. The fissures or planes of parting between these masses are called *joints*. Most frequently their direction is nearly vertical to the planes of stratification, where such exist, and they divide the rock into cubical, rhomboidal, or prismatic portions, blocks, pillars, or columns. It is owing to their various direction and frequency that different rocks assume such characteristic appearances, and may thus be often and readily distinguished when seen at a distance or shadowed in a drawing.

Some rocks have very numerous, approximate, and closed joints, as shale, some kinds of slate, and laminated sandstones; in others, as limestone, the joints are less frequent, and more open.

In coarse sandstones, they are very irregular, so that quarries of this rock produce blocks of all sizes and forms. From this cause, coarse sandstone rocks show themselves against the sea, in precipitous valleys, or on the brow of hills, in rude and romantic grandeur. The wild scenery of the Peak of Derbyshire, Brimham Crags, and Ingleborough in Yorkshire, derives attractive features from the enormous blocks of millstone grit; and the magnificent rocks which stand upon the hills and overlook the Vale of Wye, are composed of a somewhat similar material.

In clay, vertical joints are numerous, but small and confused, whereas in indurated shale they are of extraordinary length, very straight, and parallel, dividing the rock into rhomboidal masses. This may be well studied in the shale, which alternates with mountain limestone, at Aldstone Moor in Cumberland. Rhomboidal joints are frequent and very regular in coal.

In limestone the vertical joints are generally regular, and arranged in two sets, which cross at nearly equal distances, and split the beds into equal-sized cuboidal blocks; and thus the mountain limestone is found to be divided into vast pillars, which range in long perpendicular scars down the mining dales of the North of England.

In slate districts, the joints, more numerous and more regular perhaps than in any other known rock, have almost universally a tendency to intersect one another at

acute and obtuse angles, and thus to dissect whole mountains into a multitude of angular solids, with rhomboidal or triangular faces, which strongly impress upon the beholder the notion of an imperfect crystallization, produced on these argillaceous rocks since their deposition and consolidation, by some agency, probably heat, capable of partially or wholly obliterating the original marks of stratification.

Vertical joints are frequent in granite, and appear to have definite directions. The trihedral and polyhedral vertical prisms of basalt, and some other igneous rocks, coupled with their regular transverse divisions, seem to give us the extreme effect of regularity in the division of rocks by the process of condensation, from the state of igneous or aqueous expansion.

That contraction after partial consolidation of the mass is the general immediate cause of the numerous fissures of rocks, may easily be proved by a variety of facts observed in conglomerate rocks, where pebbles, and in others where organic remains are split by the joints, but cannot surely require argument. According to the circumstances of the case, this process has produced in basalt, slate, and coal fissures so regular as to give to the rock a largely crystalline structure, but left in sandstone mere irregular cracks.

From Mr. Gregory Watt's experiments on fused basalt, and some other notices by different authors, we know that a continued application of even moderate heat to a previously solidified body, may be sufficient to develop in it new arrangements of the particles, new crystalline structures, new Chemical combinations, and to cause a real transfer of some of the ingredients from one part of the mass to another; from many independent facts it is inferred, as a matter of certainty, that all the strata have locally, and the lower ones perhaps universally, sustained the action of considerable heat, since their first deposition: we seem, therefore, to be possessed of the clue which is eventually to conduct us to a thorough knowledge of the cause of the different structures observable in rocks independent of their stratification.

But though heat be taken as the leading cause of these effects, it is by no means inconsistent to suppose that some other independent agent, as, for example, Electricity, might be concerned in modifying the result. From all the recent discoveries in Electricity, it appears more and more certain, that this universal agent is excited in every case of disturbance of the Chemical or Mechanical equilibrium of natural bodies, and it is especially, and very sensibly, excited by unequal distribution of heat. Professor Sedgwick's suggestion with reference to Mr. Fox's electro-magnetic experiments on the mineral veins of Cornwall, that Electricity was probably concerned in the original production of those veins along which it now circulates, may be justly extended to the joints of rocks; in the study of which the writer of these remarks has found abundant reason to believe that the theory of the production of mineral veins is inseparable from that of the joints and fissures, in some of which the metallic substances are deposited.

In examining with attention a considerable surface of rock, it will be found that amongst the joints are some more open, regular, and continuous than the others, which occasionally stop altogether the cross-joints, themselves ranging uninterruptedly for some hundreds of yards, or even far greater distances. There may be more than one such set of long joints, and, indeed, this is commonly the case, yet, generally, there is one set

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more commanding than the others, more regular and determined in its direction, more completely dividing the strata from top to bottom, even through very great thicknesses, and through several alternations of strata. For example, there is a peculiar character of joints in each of the principal strata of the mountain limestone series, limestone, sandstone, shale, and also in the sandstones, shales, and coal of a coal district, yet, throughout the whole of Yorkshire, all these rocks are divided by the *master-joints* passing downward through them all in nearly the same direction North by West, and South by East. These master-joints, called *stines*, *backs*, *bords*, &c. are perfectly well known to the workmen, as well as some other very important yet less certain and continuous fissures passing nearly East North-East and West South-West. It is according to such joints that the experienced collier arranges his workings, and the slater and quarryman conduct their excavations. Now surely nothing can be more certain than the inference, that some very general and long-continued agency, pervading at once the whole mass of these dissimilar and successively deposited strata, was concerned in producing this remarkable constancy of direction in the fissures which divide them all. The utter deficiency of recorded observations prevents any further illustration of this important subject by reference to other districts, but it is obvious that a great principle in the construction of the Earth is here indicated, which must eventually have an important influence on Geological Theory. In the mean time we may remark, *first*, that these prevalent directions of North by West and East North East, are those of the principal *mineral veins* and cross courses in the North of England, and that they are also admitted to be very prevalent in the Southern and Western mining Countries; *secondly*, that these directions are wholly uninfluenced either by the *declination* of the strata, or by the numerous *dislocations* to which they are liable. Whatever be the direction of the dip, how frequent soever the faults, the lines of the great joints are the same. These lines are frequently the cause of particular courses in rivers, long scars on mountain sides, and subterranean channels for water. Faults, and dykes, and mineral veins very frequently pass along them, and there is little doubt that the diligent study of them will be found to throw a new light on some of the most mysterious phenomena of Geology. See pl. i. fig. 9.

In a recent Paper on the cleavages of granite in Cornwall by Mr. Enys and Mr. Fox, these cleavages are proved to follow certain lines of *definite* direction, like the well-known cleavages of slate.

Local  
changes of  
internal  
structure.

Though a little out of place, we cannot forbear to add, here a short notice of facts known in Switzerland, which distinctly prove one of the effects of heat upon common argillaceous shales, to be the alteration of its structure, so as to give a real vertical cleavage to a mass of horizontal laminae of clay, as well as that induration which belongs to slate. The lias shales of the Alps are so altered by proximity to the igneous rocks of that region, that in several places in and near the Valley of Chamouni, they are commonly mistaken by modern tourists for genuine slates of the primary system, and were always described as such by the older writers. How plainly does this teach us that the joints, cleavages, and other peculiarities of their structure, not produced in rocks by water, nor coeval with their deposition, have been occasioned chiefly by the agency of subterranean heat. What powerful aid does this generalization give

toward explaining many phenomena heretofore despaired of in Geology.

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### Mineral Composition of Strata.

Water is both a Chemical and a Mechanical agent. Under different circumstances at certain temperatures, by the help of other ingredients, as acids or alkalies, various mineral substances are dissolved in it. When, by evaporation, loss of heat, or a change in the composition of the liquid, these substances are no longer capable of remaining in solution in it, they separate in a crystallized form, or fall down, and the sediment which they occasion is called a precipitate.

By such processes lime, magnesia, and other earths and metallic oxides, are first dissolved in water, and afterwards separated from it. We find these processes, in the present order of Nature, chiefly concerned in producing calcareous marls and irregular accumulations of limestone, in lakes and in the course of certain streams and at the mouths of some rivers. So in more ancient times, the most abundant Chemical deposit from water was limestone.

The *Mechanical agency* of water is manifest at the present day in removing materials from one place and accumulating them in another. Thus pebbles and sand and clay are transported by the tides and by rivers, and accumulated in low situations in regular layers, miniature representations of those thicker strata of the same ingredients, which compose the crust of the Earth. And as at the present day some materials are transported further by water than others, and consequently more rounded by attrition, so the materials of the interior strata are likewise more or less worn and rounded, in proportion to the distance they have travelled and the friction they have suffered.

In many situations Chemical and Mechanical products are occasioned successively by the same waters, just as in the older strata limestones and sandstones alternately prevail. We see, therefore, that the ancient deposits from water, which form layers several miles thick around a great part of the Globe, are not essentially different, except in degree, from the lesser deposits now formed beneath the tides from the sea and the streams from the land.

The *Chemical stratified deposits* are principally limestones, composed of carbonates of lime and magnesia, and salt rocks characterised by muriate of soda. This is not the place to discuss points of Theory, and we shall therefore speculate no further at present on the origin of these deposits than to say, that if by any means a large supply of an alkaline carbonate, as carbonate of soda, for instance, was diffused through the sea, the effect would be a precipitation of carbonate of lime and carbonate of magnesia, which would be accumulated into strata upon the bed of the sea in thickness proportioned to the quantity of the muriates decomposed, while the supernatant liquid would be found highly charged with muriate of soda, or common salt. If the alkali were only locally diffused, the deposit would be contracted, if generally, the strata might be very extensive.

The *Mechanical deposits*, or strata, composed of earthy materials, are distinguished by the coarseness & fineness of the ingredients and by the nature of these ingredients. When the materials are of unequal fineness, and some of them are large, rounded pieces, the rock is called a conglomerate; pieces not so large constitute a sandstone, very fine particles clay. The fol-

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lowing scale will convey some notion of the gradations of size in the ingredients of Mechanical deposits.

Very fine particles generally containing 20 to 30 parts of alumine	} Clay, marl, shale, and slate.
Mixture of clay and sand	
Sand with some clay	} Argillaceous sandstone.
Small fragments of hard silicious minerals	
Sandstone including pebbles	} Millstone grit.
Large pebbles united by sandstone or clay	
Pebbles disunited	} Gravel.
Stony fragments reunited	
	Breccia.

Ingre-  
dients of  
mechanical  
strata.

Considered with reference to the nature of the ingredients which compose them, Mechanical strata form another scale.

Thus gneiss, one of the oldest of these strata, is a compound of the same ingredients as granite—quartz, felspar, and mica; but these minerals, instead of being amalgamated (so to speak) together by crystallization, are accumulated in successive laminæ more or less regular. Gneiss, therefore, differs from micaceous sandstone much less than is commonly imagined, and often has no other permanent distinctive character, than that presented by the peculiarity of its composition.

Sandstone is generally an aggregate of small fragments, or worn crystals, of quartz, with or without any argillaceous, or calcareous, or iron cement in the interstices, with or without any mica in the partings. Sometimes it very evidently contains rolled and broken pieces of crystallized felspar, such as fills the Pyramids around Mont Blanc, or the granite of Cumbria and Scotland. There is, therefore, every reason to conclude, that coarse sandstones like the millstone grit, as well as gneiss, have been derived from the waste of ancient tracts of granite.

Some beds of sandstone at Oban in Argyleshire appear to have been formed from the granular fragments of disintegrated greenstones. Sandstones sometimes extend over vast districts, and during the whole range are characterised by some remarkable mineral ingredient; as for instance, the green sand of England, France, and Switzerland, which is distinguished by the presence of a peculiar green mineral. (Glauconite.)

Conglomerates, on the other hand, are generally constituted of fragments from the neighbouring mountains. Thus the red sandstone of the Vosges mountains contains quartz pebbles derived from the slate rocks of the vicinity; the old red conglomerate of England varies in its composition according to its locality; that of Herefordshire contains much quartz, that of Cumberland is filled with pebbles of slate.

Whole se-  
ries of  
strata.

The whole series of stratified rocks then consists of alternate deposits of limestone, sandstone, and clay, with few layers of coal, rock salt, flint, iron ore, &c. The modes of alternation are different in different parts of the series, and in different situations. Thus what is called the transition limestone is enclosed between beds of slate, the carboniferous limestone alternates with sandstone and shale, the lias limestone lies in marly clays, the coralline oolite is enveloped in calcareous sandstone. Generally, the different strata are distinguishable by their mineralogical characters; but not always. When the circumstances of the deposit were nearly similar, as in the accumulation of the carboniferous limestone and some of the oolites, the strata are remarkably alike; and often particular beds of one rock are scarcely to be distinguished from beds of another rock. Thus

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some beds of lias are scarcely to be known from some calcareous layers connected with the Bath oolite, while other portions of the same rock strongly assimilate to the carboniferous limestone. The old red sandstone and the new red sandstone formations are very much alike; it would be difficult by mere mineralogical methods to discriminate the clays which separate the oolites, and many sandstones of very different epochs are almost undistinguishable. Hence we may infer that nearly the whole series of strata is the result of many repetitions of similar Mechanical and Chemical agencies operated by the same waters.

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When sets of strata are in contact, as for instance limestone lying upon sandstone, it often happens that while the limestone above, and the sandstone below, are unmixed with other matter, there is a middle set of beds composed of alternate layers of the sandstone and limestone. Thus let *a* be the coralline oolite of England, and *b* calcareous sandstone beneath; the middle beds *a'a' b' b'* are alternately oolite and sandstone. See pl. i. fig. 10.

Alternation  
of beds.

In such a case, therefore, the two strata are said to *exchange beds*, or to be subject to *alternation* at their junction, and the phenomenon seems to have been occasioned by temporary cessations of the deposit of sandstone during the commencement and progress of the deposit of limestone.

In other instances the two strata *pass into one another* by imperceptible *gradation*; as for instance, the Oxford clay of the Yorkshire coast graduates into the calcareous grit above so completely, that the bluish colour of the crumbling shale below is shaded off without any hard line into the yellow solid beds of grit above. See pl. i. fig. 11.

Gradation  
of beds.

In either case it seems quite evident that no considerable break or interval of time happened between the different contiguous deposits, one bed was no sooner formed than another was laid upon it; and by careful study of these phenomena it appears that, bed by bed, and rock after rock, the whole series of strata even to miles in thickness were successively and almost unremittently accumulated, and buried the shells and other organic Beings, which were then living in the water, or drifted into it from the land; such are, therefore, the best witnesses of the lapse of time, and of the changing condition of the land and water during the deposition of the strata.

Assuming limestones to be Chemical, and sandstones, clays, &c. to be Mechanical deposits, and putting for the present out of consideration the organic remains, which so much abound, especially in calcareous strata, we shall be able by comparison of the thickness of the several rocks to present a tolerably accurate notion of the relative proportions of Chemical and Mechanical deposits. The greatest obstacles to accuracy exist amongst the primary strata, whose thickness is exceedingly uncertain, and indeed often hardly to be determined at all.

If we take our examples of these strata from the Island of Great Britain, it may, perhaps, be found a sufficient approximation to the ratio now sought to say the Mechanical to the Chemical deposits of water are

In the Primary Series, as	500 : 1
Carboniferous System	10 : 1
Saliferous System	5 : 1
Oolitic System	4 : 1
Cretaceous System	2 : 1
Tertiary System	10 : 1

4 c

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From this comparison it would appear that the ratio of Chemical to Mechanical strata is greatest amongst the secondary deposits, and least amongst those of the primary periods; a circumstance on which depend principally the well-marked general characters of the secondary series of rocks. It should, besides, be observed, that calcareous matter very finely divided exists in nearly all the sandstones and shales of that series, and sometimes so abundantly as to change, locally, lias shale into argillaceous limestone, and calcareous grit into arenaceous limestone, or coarse oolite. In secondary strata, the great preponderance of limestones almost invariably attracts the attention and directs the classification, and thus it happens that while numerous layers of clay and sand pass nearly unobserved, or are merely noticed as *interpolated beds*, almost every calcareous bed has its characteristic local name. The almost universal diffusion of calcareous matter through the mechanical strata of this large class, combined with the greater regularity and persistence of the limestones, generally impresses on the attentive observer a peculiar theoretical notion as to the cause. He soon learns to consider the operations by which sandstones and clays were accumulated as of short duration, and intermittent action, like the periodical floods of a river, or some less regular inundations; while the production of limestone is regarded as the result of one continuous and almost uninterrupted series of Chemical changes. This opinion, strengthened by the curious gradations between the calcareous and the sandy or argillaceous laminæ, and by the frequent alternation amongst even their thinnest portions, derives very plausible arguments from the distribution of organic remains through the several strata. In some cases these teach us plainly that sandstones, even of great thickness, were the products of temporary and often of very local floods, which swept down from the land the scattered spoils of the animals and plants then in existence; but, tried by the same tests, the calcareous rocks appear to have been of slower and more equable production, in clearer and more tranquil waters. Is not this exactly in harmony with the present system of natural operations?

#### Condition of Organic Remains.

What organic remains occur in the Earth.

The fossil remains of ancient plants and animals have been the theme of admiration for the learned and the vulgar in every Historical Age. The difficulty of understanding how the shells of the sea and the plants of the land could be inclosed in hard rocks, in prodigious abundance and of exquisite beauty, led Plot and Lwyd, and even partially Ray and Lister, together with some continental writers of eminence, to adopt a most strange hypothesis. Plot advanced the extreme absurdity that these beautiful monuments of the ancient condition of the Earth had in fact never been shells or plants, but were merely *lusus nature*, deceptive resemblances produced by some plastic power in the interior of the Earth. Swift well ridicules this notion of *lusus nature* in his *Voyage to Brobdingnag*.

This ridiculous fancy has long since become obsolete, and the "formed stones" dug out of the bowels of the Earth are now recognised as the original inhabitants of its primeval land and water.

The differences of condition between them and analogous living objects, the mode of their conservation, the manner of their distribution in the Earth, the relative

periods of their existence and destruction, constitute a vast, lucid field of research, through which many avenues are already traced toward the secret powers which presided over the formation of the Earth.

**TERRESTRIAL PLANTS** abound in certain strata, especially in the coal districts, where the seams of coal are nothing but vast layers of vegetables swept down into estuaries or lakes, and there covered by sand and clay, and changed by Chemical depositions.

**ZOOPLANTES** both stony and flexible, many of them belonging to genera now in existence, fill our limestone rocks with their most delicate and beautiful organization; with them lie abundantly columns of crinoidal animals, and crusts and spines of echini.

**MOLLUSCOUS ANIMALS** are now the most numerous of all the tribes of Beings which overspread the bed of the sea, and their shelly coverings are also the most abundant of all the organic fossils.

Of the **ARTICULATED ANIMALS**, the most abundant remains are lobsters and crabs, and other crustacea, analogous to existing types; besides trilobites and others to which nothing similar has yet been found in the modern ocean. Fossil insects are very rare; and confined to almost a few comparatively recent deposits from fresh-water.

No one acquainted with the structure of the invertebral Animals previously mentioned, can view their crusts, shells, and other hard appendages in the fossil state without being struck on the one hand with the wonderful perfection of all their minutest organization, and on the other with the uniform and almost total absence of their soft parts. The bodies found "petrified" in the rocks were originally durable. Similar substances are now capable of conservation in our cabinets: but the softer animal parts which they protected—the muscles, the viscera, and even the ligaments—have almost uniformly disappeared. Hence it appears a just conclusion that the process of petrification, the substitution of mineral for animal matter, was slow and gradual.\*

The same result follows a similar examination of the fossil reliquæ of vertebral Animals. For though we find in tolerable plenty the bones and teeth of fishes and reptiles, the skin and other softer parts are usually deficient. The bones of birds are excessively rare, and those of mammals are mostly confined to the least ancient of all the Neptunian deposits.

In consequence of this decay of the softer parts, many of the hard parts of Animals are found disjoined and separate. Crusts of lobsters, bivalve shells, vertebral columns, originally bound together by perishable ligaments, are very generally found in detached portions, precisely as happens to similar objects at the present day; and generally this is all the injury they have sustained. The delicate stræ, sharp spines, and other ornaments, are usually so well preserved that no one can believe that they were ever removed far from their native haunts. They were, in fact, quietly buried on the bed of the sea; living or dead, entire or decomposed, just as such Beings are found at the present day, when by any method the bed of the sea can be examined.

And just as at the present day where currents run strongly in the sea, shells are worn by friction in the

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What portions of the original structures are preserved.

In what state interbedded.

\* The ligament of *Cardium truncatum* is preserved in marlstone at Rosebury and Staithes in Yorkshire, and impressions of the arms of *Cephalopoda* are found in the oolite of France.



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sand and by beating against one another, and trees carried down by rivers are scattered in fragments; so in certain of the old strata we find similar proofs of rapid currents from the land, and temporary turbulence in the primeval ocean.

All the accidents of imperfection and disunion of parts happened, of course, before the organic bodies were enveloped in the earthy deposits.

Subsequent  
changes of  
composition.

The changes by which they have been converted to petrifications did not, probably, commence till after they were thus enclosed.

These changes in the substance of the fossil reliquie are different according to the original nature of these bodies, the kind of matter in which they are enveloped, and the other circumstances by which they were surrounded.

We shall make some remarks on the conservation of the principal classes of organic fossils in the different kinds of matter.

In plants.

Dried vegetable substances may be considered as compounds of carbon, oxygen, and hydrogen, with small and variable proportions of other substances.

Carbon . . . . . 40 to 55 per cent.

Oxygen . . . . . 40 to 50

Hydrogen . . . . . about 5

Of these ingredients the most volatile parts, viz., the oxygen and hydrogen, seem, in many cases, to have vanished, but the carbon generally remains, and is either almost pure, as in some kinds of coal; mixed with bitumen, as in jet and most coals; mixed with carbonate of lime, as in the remains of coniferous wood in the lias and oolite; or blended with flint or pyrites in these and other strata. Generally, as might be expected, the vegetable substance is most completely disguised by earthy admixtures in porous strata, such as oolite or sandstone; and, on the other hand, the original carbonaceous skeleton of the plant is preserved with the least change in close, compact materials like clay, shale, or ironstone. This is strikingly exemplified in the coal-districts, where ferns and other plants which lie in the shales are changed to bright inflammable coal, while the very same species in coarse gristone are represented only by a brown, ferruginous stain. Coal is most evidently a product on a large scale, precisely identical with the thin filmy remains of ferns and reeds which accompany it. A vast mass of plants accumulated beneath the ancient sea, or in sea-like lakes, was covered up and buried by successive deposits of sand and clay, and under this heavy pressure, and hermetically sealed, chemical decomposition went on, and a new chemical product, coal, was elaborated; which, upon analysis, is found to contain the usual ingredients of vegetables, in proportions no otherwise different than was to be expected from the loss of some of the more volatile parts.

In this respect, coal exhibits many variations. That of Kilkenny, for instance, has only four per cent of volatile matter; Cannel coal has about fifty per cent.; the Kilkenny coal contains ninety-two per cent of carbon, common coal about seventy per cent. carbon, and thirty per cent. oxygen and hydrogen.

In corals,  
shells,  
crusts.

The internal and external hard parts of invertebral animals, zoophytes, mollusca, and articuloza, are much allied in composition. They generally contain the same durable and the same perishable parts; carbonate of lime, alone or with a small admixture of phosphate of lime, gives them firmness, and the flexibility which some of them possess is derived from gelatine.

The process of petrification consists in the loss and replacement by a different substance of one or other of these ingredients. The first degree of change which these fossils have experienced, is when the coralline or shell retains not only its external figure and appearance, but even its internal texture, and almost all its original substance. Such specimens look as if obtained from the sea-shore in a dead state, with no other apparent loss than that of colour and brilliancy. This state of conservation may be said almost to characterise the organic remains of the strata above the chalk.

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Loss of colour, &amp;c.

The next step in the process of petrification is illustrated by many shells which lie in the gault and other clays; they have lost their gelatinous portion, and are, in consequence, become light and friable, but have not received into their pores any extraneous earth.

Loss of gelatine.

The third variation is occasioned by the gradual substitution of an extraneous substance, as flint or pyrites, into the pores left by the decay or waste of the original body; thus the fibres of wood and sponge, and the plates of corallines and shells, have been changed by little and little into a different substance, which often represents with most faithful accuracy the minutest structure of the original. It is evident, therefore, that this great change was accomplished gradually, the new particles taking successively the place of those removed by decomposition.

Insinuation of new matter.

These processes of decomposition and substitution of new ingredients, which probably commenced at the periods when the several fossils were imbedded in the rocks, are to this day continued, and often exhibited with remarkable energy. Those products of modern operations of Nature which go under the vague name of recent petrifications are so various in their character, that a detailed study of them, in relation to their accompanying circumstances, could not fail to furnish data for explaining some of the most remarkable stages in the process of mineralization, to which organic bodies have been exposed in the Earth. In proof of this, we shall content ourselves at present with putting in comparison a well-known peculiarity in the mode of conservation of certain fossils, and an instance of the same singularity in recent petrifications. It is often to be noticed that while the external cell of an ammonite, or the larger part of the spiral cavity of a melania, is filled by the coarse matter of the enveloping rock, the closed chambers of the former, and the smallest volutions of the latter, are filled with crystals of calcareous spar. The well-closed shells of productæ, terebratulæ, &c. are often lined internally with calcareous spar, quartz, or even galena, while this never happens, perhaps, to shells whose valves did not fit very exactly. In fossil wood it happens very often that the external parts are merely jet or coal, while the central portions are changed to carbonate of lime; and, in general, all these examples appear to agree in proving that the mineralizing substance was transferred to its repository in the innermost cells and smallest pores by a kind of secretion, quite through solid septa of shell, and considerable thickness of even dense stone. The recent petrifications of hazel-wood and nuts, from the alluvium of Ferrybridge in Yorkshire, (*Phil. Mag.* 1828.) prove that the same remarkable transfer of particles through other substances, with the same elective attraction for these particles possessed by the finest textures and smallest cavities, accompany the ordinary modern aqueous deposits of carbonate of lime. In the alluvium of

Analogous modern processes.



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this place, a certain part of a large collection of hazel-wood and nuts was found mineralized by a subterranean spring from the neighbouring limestone, and it was remarkable that the central woody core of a hazel-branch or root was wholly converted to stone, while the bark and outer layers of wood were unchanged, the kernel of the nut was petrified within its brown unaltered membrane, and the internal fibres of the shell within the still woody surfaces.

Dissolution  
of shells,  
corals, &c.

The fourth condition is exemplified in limestone and sandstone rocks, from which the whole of the substance of shells, corals, &c., has been dissolved and carried away by water. In consequence, a cavity is left in the rock bearing the impression of the exterior of the shell or coral, and in this cavity is a mould or cast of the interior. Thus the "screwstones," as they are called, have been cast or moulded in the cavities of crinoidal columns.

Replacement  
of  
shells,  
corals, &c.

The most extreme case of mineralization or petrification is produced by a process in addition to that just described, when the cavity left by the removal of the shell or coral is again filled up with crystals of calcareous spar, deposited by water filtrating through the stone. Sometimes, only a few crystals connect the inner mould or cast to the exterior impression, but generally, the whole cavity is filled by the spar, which thus represents truly the shape of the original body, but displays no trace whatever of its internal texture.

Dependence  
of these  
changes on  
the nature  
of the rocks.

There is in general a certain accordance and relation between the condition of organic fossils, and the nature of the rock which incloses them. In the green sand almost all the shells are silicified, in the oolitic rocks many are changed to calcareous spar, in the clays very slight changes have happened to any of the organic remains.

On the other hand, the original nature of the organic substance has very much influenced its mode of conservation. Echinoidal and crinoidal remains are almost invariably converted to a peculiar kind of opaque, calcareous spar, in whatever strata they occur; gryphææ and astrææ retain their laminæ, inoceramii and belemnite stheir fibres.

Remains of  
vertebrata.

We come now to the vertebral division of Animals. Their soft portions have perished, but their teeth, bones, and scales remain, either connected or separated in consequence of the decay of the ligaments, cartilages, &c.

The hardening ingredient of bones is principally phosphate of lime, that of teeth is a mixture of phosphate and carbonate of lime. It is generally the fact that their gelatinous or membranous portion has been diminished, and their earthy admixture increased, by the subterranean Chemistry to which they have been subjected, and, in consequence, their Specific Gravity is much augmented.

#### Distribution of Organic Remains.

Number of  
species.

The researches of modern Naturalists have been singularly successful in bringing to light a vast number of new species or supposed original types of organization. The catalogues of living plants and Animals have been enormously lengthened in consequence of more rigorous investigations among the smaller tribes. In like manner the number of known organic fossils has been of late years so greatly augmented, that in some departments they nearly equal, and, in others, exceed the living ranks of Creation. In Great Britain alone, 1500 species of organic remains have been well described and figured;

and it is probable that the numerous tribes of undescribed zoophyta, mollusca, crustacea, and plants, will swell the catalogue to 2500 species at least. An equal number of other kinds adorn the cabinets of Continental Europe. Generally speaking, the principal deficiencies in the catalogue of fossils, as compared with that of living organic forms, are found in the aerial and terrestrial races.

Insects, birds, land reptiles, and mammalia are the rarest of fossils. We are, however, not to conclude that the ancient land was uninhabited by those tribes, because we do not find their remains in the strata which were formed on the bed of the ancient sea. Such remains are very rarely carried down and buried beneath modern lakes, and therefore were much less likely to be entombed beneath the deposits of the ocean.

In the following Table, M. Adolphe Brongniart compares the extinct flora of the Ancient World at four several periods with the vegetation which now covers the Earth. The general proportion is about 100 living plants to one fossil one.

	Première Période.	Deuxième Période.	Troisième Période.	Quatrième Période.	Epoque Actuelle.
1. Agamées . . . . .	4	5	18	13	7,000
2. Cryptogamées celluleuses	—	—	—	2	1,500
3. Cryptogamées vasculaires	222	8	31	6	1,700
4. Phanérogamées gymnospermes	—	5	35	20	150
5. Phanérogamées monocotylédones	16	5	3	25 ?	8,000
6. Phanérogamées dicotylédones	—	—	—	100 ?	32,000
Indéterminées	22	—	—	—	—
	264	23	87	166	50,350
	540				

The immense disproportion between the numbers of fossil and living vegetables will probably not justify the inference that in ancient periods only a few species of plants covered the surface of the Earth. Only a small proportion of the vegetable tribes now growing upon the Earth are swept down into the sea, comparatively but a very trifling number would be carried there by even the most violent floods, and therefore the few hundred species of fossil plants are probably only a very small selection from the numbers that really covered the Earth. Nevertheless these few relics may be reasonably supposed to have been amongst the most abundant of the plants then in existence, and may be usefully employed in characterising the several periods of deposition.

Thus it appears that in the most ancient of the four periods defined by M. Brongniart, existing before the deposit of magnesian limestone, the most abundant fossil plants belong to the vascular cryptogamic class, including the natural families, ferns, equisetaceæ, lycopodiaceæ, &c.; that in the third period, which includes the oolitic and cretaceous rocks, cycadæ are especially numerous; and in the fourth or tertiary period the more complicated dicotyledonous plants appear, and thus gradually conduct us to the vegetation of the present day.

Zoophytes, the first tribe of Animals to which we shall advert, are almost entirely marine. The flexible corallines, which contain the smallest portions of earthy ingredients, are but rarely seen fossil, but the stony corals

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**Geology.** and the hard echinodermata are exceedingly abundant in nearly all the secondary deposits **Ch. I.**

The following Table, from which Lamarck's collated polypi are excluded, will convey a good general notion of the relative proportions of recent and fossil zoophyta.

	Described British Species.		Recent Species described by Lamarck.
	Recent.	Fossil.	
Polypi, nude.....*	5	—	18
Celluliferous flexible ..	67	—	117
stony ....	21	26	64
Lamellated .....	3	30	134
Corticiferous .....	12	2	132
Carnose .....	47	25	194
	155	83	659

The proportion of British species is as 2 recent to 1 fossil.

Radiata	Fistulida .....	11	—	44
	Stellera .....	19	5	76
	Echmida .....	9	45	88
	Crinoidea .....	1	27	3
		40	77	211

The proportion of British species is as 1 recent to 2 fossil.

It has often been thought, that the remarkable contrast in the proportions of the fossil and recent zoophytes of Britain might be explained by supposing that the ancient climate was hotter than at present; that, in fact, the former productions of our Northern Seas were of a tropical character; and this conjecture agrees with the deductions which may be drawn from similar comparisons in the other tribes of Animals. But the extreme rarity of flexible corallines is not confined to the strata of Britain, it is recognised over all Europe, and seems, at least in part, owing to their more perishable nature.

The contrast is equally striking among the radiaria; and it is especially worthy of remark, that the numerous group of crinoidea, so characteristic of the fossil races of a former World; belongs chiefly to the lower and more ancient members of the stratified rocks.

Passing over the remarkable Animals included in Lamarck's class funicata, which appear to connect the zoophyta with the mollusca and of which, being mostly perishable, no fossil species is yet recorded, we arrive at the class of conchifera, or bivalve molluscous Animals.

**Conchifera.** Shells are the most numerous of all the organic treasures buried in the strata; a circumstance which might naturally have been expected from their durable constitution, their vast abundance in the present system of Nature, and their aquatic existence. When a lake is drained we find great quantities of shells in the silt which has filled its bed, but the remains of fishes and insects, and even of plants, are rarely met with.

	Described British Species.		Recent Species described by Lamarck.
	Recent.	Fossil.	
Lamellibranchia.			
Plagyozyona .....	186	396	800
Mesomyona .....	29	198	197
Brachiopoda.			
Equivalvia .....	—	4	—
Inequivalvia .....	5	159	15
	259	657	1012

The first thing which strikes us on comparing the catalogues of British recent and fossil bivalves, is the greater absolute number of the extinct species. The proportion is at present three to one, and when the strata shall have been as thoroughly explored as the

shores, the number of our fossil conchifera will probably amount to a thousand, and be to the recent kinds as four to one. **Geology.** **Ch. I.**

On more minute comparison, we learn that the most remarkable discrepancy in the proportions is found in that singular tribe the brachiopoda, of which above 150 fossil species are already described, while the recent kinds do not exceed five. Perhaps these numbers on both sides will be changed by further discoveries. At least fifty species of spiriferæ, productæ, and terebratulæ remain to be described from the lower calcareous strata of England.

We next arrive at the gasteropodous mollusca with simple univalve shells. **Gasteropoda.**

These we shall arrange in groups according to their places of residence.

	Described British Species.		Recent Species described by Lamarck.
	Recent.	Fossil.	
Marine .....	210	398	1473
Estuary .....	—	21	22
Fresh water .....	31	23	50
Terrestrial .....	53	21 ?	274
	294	463	1822

\* Considerable difficulty is experienced in referring certain fossil shells to their respective recent analogues; and in consequence it is very probable that many of the species above, ranked as estuary and land shells, deserve a different arrangement. This is particularly the case with respect to the helices, helicinæ, and melaniæ.

According to the ordinary notion of their food, gasteropodous mollusca with shells may be ranked thus:

	British.		General.
	Recent.	Fossil.	Recent.
Phytiphaga .....	233	263	786
Zoophaga .....	61	200	1036

We are not aware that there are any fossil shells of the Cephalopoda class of pteropodous mollusca, but the remains of the cephalopoda are inconceivably numerous, and far surpass the recent kinds in both variety and magnitude.

	British.	
	Recent.	Fossil.
Cephalopoda .....	46	308

The fossil cephalopoda belong for the most part to genera not yet discovered in a living state.

The fossil species of vertebrated animals are comparatively very few, and some of them, especially fishes, not so perfectly characterised as to admit of much accuracy in their arrangement.

The following summary is chiefly taken from Mr. S. Woodward's Synoptical Table

British fossil		
Fishes, Fresh water. ....	29	In various strata.
Reptiles, Marine .....	26	
Reptiles, Land .....	26	
Birds .....	6	In "diluvium" and alluvium.
Mammalia .....	1	In Stonesfield slate.
	28	In diluvium, alluvium, &c.

Considered according to their situations of life, the British organic remains present the following results: **fossil species.**

In the strata.		
Terrestrial	{ Vegetables .....	90 and more.
113	{ Shells .....	21 ? Mostly very doubtful.
	{ Reptiles (Pterodactyl) 1	
	{ Mammalia .....	1
Fresh water	{ Vegetables .....	5 or 6
56	{ Shells .....	40 ? { The genus Unio requires reconsideration.
	{ Fishes .....	11 ?

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Estuary 28	Shells .....	21 ?
	Fishes .....	
Marine 1139	Reptiles (Crocodile, Emys, Trionyx) .....	7
	Vegetables .....	3 or 4
	Zoophyta .....	83
	Radiaria .....	77
	Shells .....	909
	Crustacea .....	30
	Fishes .....	18
	Reptiles .....	19

*In superficial alluvium, diluvium, &c. caves, &c.*

Birds .....	6 species.
Mammalia .....	29

European  
fossil spe-  
cies.

Such are the numerical relations resulting from a comparison of the extinct British species of Animals and plants on the one hand, with the recent organic Beings of Britain, and universal living races of the Globe on the other. These relations would doubtless have been considerably modified, had we found it possible to introduce accurately all the European species of fossils. But this task, owing to the still imperfect state of discovery on the subject, but far more to the unhappy confusion of synonyms, is at present hardly practicable. However, not wholly to neglect so important a datum, we shall take advantage of the information conveyed to us by Brongniart, Deshayes, Goldfuss, Dalman, and other writers, to compile a numerical statement of the most remarkable and ascertained European fossils, and to put them in comparison with a corresponding estimate of the existing species.

*Remains of Animals.*

	In the strata.	In superficial accumulations	Living estimated.
Mammalia .....	35	109	1100
Cetacea .....	8	—	—
Birds .....	few	few	5000
Reptiles .....	71	—	2100
Fishes .....	183	—	5500
Insects .....	74	—	100000
Crustacea .....	104	—	500
Amolosa .....	104	—	1000
Cephalopoda .....	788	—	100
Pteropoda .....	5	—	50 ?
Gasteropoda, Zoophaga .....	107	—	1700
Phytophaga .....	773	—	1400
Conchifera, Brachiopoda .....	379	—	40
Mecomyona .....	515	—	350
Plagmyona .....	1132	—	1400
Tunicata .....	—	—	—
Radiaria .....	278	—	1000
Polyparia .....	476	—	1000
	6027	109	122190
Plants .....	540	—	52000

*Distribution of Organic Remains.*Number in  
different  
rocks.

The animal and vegetable fossils are very unequally distributed. For while some rocks are wholly filled with shells, others are absolutely devoid of them. Thus the forest marble and coarse upper beds of Bath oolite are composed of little else than shells, while the sandstones of a whole coal district may contain not one. This does not depend either on the absolute depth from the surface of the Earth, at which any rock may be found, nor yet upon its relative depth in the series of strata, but it is a circumstance established by experience, and of which some of the causes remain to be determined. The following Table exhibits the proportionate number of species of fossils in all the principal strata of the North of England, arranged according to their order of superposition.

	Thickness.	No. of fossil Species.	Ratio. Spokes.	Feet.
Chalk .....	505	43	1 to 12	
Galt of Speeton .....		67		
Kimmeridge clay .....	150	5	1 to 2	
Upper calc grit .....	60	5	1 to 12	
Coralline oolite .....	60	125	3 to 1	
Lower calc grit .....	80	40	1 to 2	
Oxford clay .....	150	36	1 to 4	
Kelloway rock .....	40	60	3 to 2	
Cornbrash .....	5	37	7 to 1	
Upper carboniferous series .....	200	30	1 to 6	
Forest marble slate .....	30	82	3 to 1	
Bath oolite .....				
Lower carboniferous series .....	500	21	1 to 24	
Lower oolite .....	60	91	3 to 2	
Lias and marlstone .....	850	115	1 to 7	
New red sandstone .....	?	none		
Magnesian limestone .....	215	30	1 to 7	
Coal system .....	3000	100 ?	1 to 30	
Mountain limestone .....	2500	200 ?	1 to 12	
Old red sandstone .....	?	none		
Slate system .....	6000	20	1 to 300	

Granitic rocks devoid of fossils.

It is necessary to remark, that the proportions derived from the preceding Table would apply only in a general way to the same strata in the South of England, for there the number of organic remains in the chalk is, at least, triple of that in the Table, the thickness remaining the same, while the mountain limestone is considerably less rich in fossils. Still less is such a Table to be viewed as a representative of the results of researches on the Continent, for there the red sandstone formation contains a very large suite of organic remains, both vegetable and animal, while neither have yet been found in this rock in England.

We shall now consider what are the *kinds of fossils* which are contained in these various strata: in other words, in what order of distribution the fossils are arranged in the Earth.

A great difference between the present system of Nature, and that of which the relics are preserved in the Earth, is obvious to any one, who considers the relative proportions of the different classes of each. But the most decisive proof of the enormous changes which have happened in this respect is found by a minute comparison of the families, genera, and species. For except in the superficial and comparatively modern accumulations from fresh-water lakes, floods, or tides, and in the most recent of all the strata, scarcely one specimen of all the thousands of existing kinds of plants or Animals is found buried in the Earth.

The Earth contains the records of an ancient system of living Nature, which in its great outlines was calculated much like that which we now see in operation; but of which all the details were different. The ancient sea nourished Saurians, but they were not our crocodiles; fishes which are generally unlike the finny tribes of the existing era; innumerable shells planned on the same general principles, but executed to different patterns. The plants and the Animals of the ancient Continents performed the same relative functions as the vegetable and animal races of to-day, and formed part of a similar combination, but, as the circumstances of the Globe are now not the same as then, the forms and structures of its plants and its Animals are adapted to the difference.

But it must be obvious that to view the whole multitude of extinct Animals and vegetables as the products of one ancient era, to confound together all the various different strata which were successively the beds of the

Successive  
eras of fos-  
sil tribes.

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ancient seas, would be to destroy the meaning of all the monuments which Nature has preserved of the long periods and successive developements through which our Planet passed before the completion of its present beautiful arrangement. Each stratum was successively the bed of the ancient oceans or lakes, and the remains with which it is filled were the creatures then living in the waters or growing on the land. \*Each stratum, therefore, belongs to a particular period; it is the museum or repository in which Nature has preserved the plants and Animals of that period; and the Geologist, no longer confined to the mere comparison of recent and extinct species, finds in the Earth the proofs of many successive creations and abstractions of life, many systems of Nature; and by strict analogy and ample induction looks back through a long vista of revolutions, till the view is lost in the dimness and distance which hide the remote epoch, of which no evidence remains to show that the Earth was then inhabited by living creatures.

Terrestrial and marine fossils not usually abundant together.

The organic monuments of ancient Nature are either of marine, of fresh water, or of terrestrial origin. The corals, and by far the greater number of shells, are marine, certain strata are filled with lacustrine reliquæ, and others with the spoils of the land.

There is in general the most remarkable and constant distinction and contrast between the rocks which are filled by marine remains, and those which enclose terrestrial productions. Calcareous strata generally are the most richly filled with the spoils of the sea, zoophytic, molluscous, and vertebrated Animals; but they rarely contain terrestrial plants. Sandstones and shales, on the other hand, are almost the exclusive repositories of terrestrial plants, but, unless they are calcareous, they more rarely contain marine exuvie. The reason seems to be that the calcareous strata were deposited slowly and in tranquillity beneath the waters of the sea, and thus enveloped the dead and decaying animals of the ocean; while, on the other hand, the sandstones and shales were more rapidly aggregated, in water too agitated to favour the accumulation of marine reliquæ. When we find in them few or no traces of land plants, we may perhaps presume that the currents to which they may owe their origin were marine, but when they are charged with ferns, equisetæ, and other terrestrial plants, it seems evident that violent land-floods contributed to their accumulation.

Oceanic deposit of limestone.

The deposition of limestone by Chemical precipitation, would probably happen over a large portion of the bed of the sea, and be abundant in proportion to the depth of the water: hence the strata of limestone would thicken toward the centre of the oceanic basin. They would also be more condensed, and of more uniform texture, and perhaps of purer composition, in that direction; and since, from accurate observations of the habits of recent marine Animals, it appears that they do not multiply so much in the darkness of very deep waters as nearer the shore, we may conclude that fewer marine shells and corals, &c. should be found near the central points of the basins of strata.

How remarkably all these conditions agree in the limestones of the Alps, which appear to have been uplifted from very deep water, needs only to be mentioned. There, the rocks corresponding to our oolite, are vastly thicker, more dense, and incomparably poorer in shells, than the same strata toward the borders of the European basin. And if, in proceeding through France to the Alps, we stop to consider the Jura, we shall find its

oolites, in respect of thickness and hardness, and quantity of shells of an intermediate character.

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On the other hand, sandstones and clays, being Mechanical deposits from agitated water, should of course be most abundant along the margins of the ancient sea, and at the mouths of ancient rivers, where the strongest movement of the waters happened. They are essentially littoral formations, and should be found thickest, and most numerous, and most varied in character, toward the borders of the basin, where the limestones are the thinnest. And as the forces of tides and currents, however powerful, are irregular and limited, the Mechanical aggregates which they occasion must be, and in general are, more confined and irregular than the wide Chemical deposits of the deep sea.

Littoral deposits of sandstone, shale, &c.

This supposition likewise agrees perfectly with what we observe in comparing the oolitic system of the Jura and the Alps with that of Northern France and England; for the clays and varied sandstones which diversify this system in the latter Countries, and separate it into many distinct groups, are scarcely to be traced in the Alps or the Jura.

Another case in point is furnished by the carboniferous limestone series of England. This limestone in the South of England is so little divided by Mechanical strata, that in the Mendip Hills, near Bristol, and around the Forest of Dean, it is commonly supposed to be one thick rock.

In the North of England it is much and evidently divided, and the number and thickness of the partings of shale and sandstone, and coal, increases continually Northwards, while the total thickness of the limestone beds grows less and less. At the same time the organic remains seem to become, if not more numerous, (if point as yet difficult to be determined,) certainly more varied in form.

The oolitic system of England presents us with another valuable illustration of the same doctrines.

The oolites of Somersetshire, Gloucestershire, and Lincolnshire form a long range of hills, and are only, and that not universally, divided by partings of clay and marly limestone. But as we advance into Yorkshire we find these spaces augment, and the widening intervals filled up by thick deposits of sandstone, shale, plants and coal, which predominate so much in the section as almost to obliterate the separated, attenuated, and deteriorated limestones. These, however, are filled even more than usually with marine exuvie.

The concretionary or oolitic structure is, perhaps, more decided and constant toward the borders of the strata. It becomes irregular, and at length fails in proportion as the limestone is mixed with earthy impurities. At the extreme Northern range of the degraded oolitic system in Sutherland this structure is nearly lost; it is irregular in the impure limestones of Yorkshire, becomes perfect in the homogeneous strata of Gloucestershire and Somersetshire, assumes more compactness in the Jura, and changes to dense limestone in the Alps.

This is exactly what, *à priori*, would be expected to happen. Amidst the turbulence and admixture of the littoral deposits, a process so similar to crystallization could happen but seldom and unequally, there would be a point at a certain distance from the shore at which the disturbance would prevent regular crystallization and yet would permit of concretion through the calcareous sediment, and still further the limestone would be more compact and subcrystalline.

Coarse conglomerates, for similar reasons, would be

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most abundant toward the shores and more local than the finer sandstones and clays; which also would be most likely to contain the remains of plants, as these might be long suspended in the unsettled water, and be transported along with the finer matter.

The distinction here insisted on between *conchiferous* and *phytiferous* rocks, is so important, that we must, in speaking of the distribution of organic remains in the Earth, consider them apart; and while from the former we deduce the ancient condition of the sea at several epochs, the latter will furnish us with analogous data from which to reason on the state of the contemporaneous dry land.

We shall commence with the MARINE FOSSILS, and investigate the manner of their distribution under two general heads: 1st, their relation to the Chemical and Mineralogical composition of the strata; 2dly, to their relative antiquity.

Analogous  
fossils in  
similar  
rocks.

If the marine fossils are distributed in the rocks according to their Chemical nature, we shall find that similar rocks contain similar fossils. This is certainly the case with respect to the zoophytic animals, for these are almost confined to the calcareous strata. Corals, and various Animals of the class radiaria, abound in the transition limestone, carboniferous limestone, oolites, and chalk.

The remarkable brachiopodous bivalves, as spirifera, producta, pentamerus, terebratula, are also by far most abundant in the calcareous rocks. Gryphææ and smooth oysters are found in the argillaceous strata of the South of England, from the lias upwards to the chalk.

The organic remains of the different limestones of the oolitic formations have very remarkable general analogies. Thus the inferior oolite and the coralline oolite, the fuller's earth rock, and the cornbrash, hold very many closely analogous species. But it must be remembered that the functions of the oolitic system in England are in some degree local, and probably dependent on the littoral character of the deposits, and that in other parts all these subordinate strata coalesce together into one hardly divisible mass of oolitic limestone. The resemblance of fossils in these strata may, therefore, rather be the result of their nearly contemporaneous existence, than of the mere similarity of the Chemical composition of the rock.

These are the most remarkable instances of the association of certain organic forms with certain Chemical compounds; they are important data to support the opinion that, generally, fossil remains lie near the places where the Animals perished. But it is evident that these few analogies by no means establish a general law. On the contrary, when we proceed to consider in this point of view a large number of species, the resemblance between the organic contents of one limestone and those of another of considerably different age, is very slight and shadowy. And as no other strata than the limestones exhibit it in a striking degree, it is evident that some other cause than the Chemical composition of their repositories has regulated the inhumation of fossils.

That cause is the subject of our next examination, the relative antiquity of the strata.

That a strict connection does really obtain between the age of a rock and the organic remains which it contains, is made evident by comparing a few well-ascertained facts.

Different  
fossils in  
strata of  
different  
age.

The mountain limestone of the North of England contains, perhaps, 200 species of animal remains; the lias 115; and the chalk 43. Now of all the 358 species contained in the mountain limestone, lias, and chalk, respectively, there is *not one* which is found in two of these rocks. Neither of these strata contains a single fossil which is found in either of the others. Between the era of the formation of the mountain limestone, and that of the lias, the whole animal population of the sea had been entirely changed; and a similar complete renewal took place before the chalk was deposited. And in the Southern parts of England the chalk is covered by other more recent strata filled with shells and other marine Animals, entirely different from all those which lived and died before.

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Further investigation has demonstrated, that conclusions thus drawn from local researches apply with considerable accuracy in other situations, even at great distances where the same strata occur. A catalogue of the corals, crinoidal remains, productæ, spiriferæ, terebratula, orthoceratites, and trilobites, of the mountain limestone in Yorkshire, may be employed for labelling the fossils collected from the same rock at Namur and Liege; the lias of Whitby contains many of the same ammonites, and the same Saurian skeletons as the contemporaneous beds at Lyme, and in Westphalia and Wirtemberg; and the remarkable echin and belemnites of the English chalk accompany that rock through France and Poland to the shores of the Baltic.

Identical  
fossils in  
rocks of the  
same age

The same observations have been made on the other conchiferous strata of England. Each has been traced through the Island, and its organic treasures have been explored at every point, and in this manner satisfactory proof has been collected, that along its whole course the fossils which it contains are almost entirely the same. The researches of foreign Geologists have demonstrated the truth of this law for the greater portion of the European basin of strata. The figures and descriptions of the English fossils are referred to by the Geologists of France, Switzerland, and Germany, and no doubt remains that each extended stratum is the repository of the Animals inhabiting the sea at a certain period in the Earth's formation, exactly as the earthy bed of the present sea now envelopes the remains of its present corals, shells, echin, and fishes.

The general principle, therefore, which regulates the distribution of organic remains in the Earth may be thus expressed. They are associated according to the periods at which they existed; and they are enclosed in the rocks which were at those times deposited by the water. And as in ancient times, much more than at present, the animal remains over considerable breadths of the bed of the Northern Sea were nearly identical, *strata of the same age contain generally the same fossils.*

General  
principle  
Smith.

Also because the inhabitants of the ocean were, in the course of time, completely changed, the old races having been extinguished and new ones brought forward to occupy their places, *strata of different ages contain generally different fossils.*

These important propositions form the groundwork of the history of the stratified rocks, and must be ever present in the mind of the modern Geologist. The honour of their discovery belongs to Mr. William Smith, an engineer of eminence, who, being employed in 1790, and the following years, in surveying collieries, and planning and executing a canal in Somersetshire,

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established the English system of Geology upon the following propositions.

"That the strata are laid upon one another in a certain definite order of succession or superposition, may be traced in continuity on the surface of the Earth, and may be discriminated when of different ages, and identified when of the same age, by their imbedded organic contents."

Gradual  
changes in  
the races of  
organic  
being.

By comparing a sufficient number of fossils from all the several strata with analogous living tribes, we discover that those fossils which more nearly resemble the living kinds belong to the strata which were deposited at the least ancient period; as for example, the crag shells of Norfolk and Suffolk, the London-clay shells of Hampshire and Highgate, which are all more recent than the chalk.

In these situations we find the families, genera, and even species of shells so similar to recent kinds existing somewhere or other in the Ocean, that though they are often very different from the productions of our neighbouring seas, we not the less perceive that they belong to a system very like that now established.

On the other hand, those fossils which present the least resemblance to their successors in the modern system of Nature, belong to the older, and especially the oldest of all the conchiferous strata. It is in the transition and carboniferous limestones that the singular brachiopodous bivalves, producta, spirifera, pentamerus, the remarkable genus orthocera, the zigzag ammonites, the still unexplained tribes of trilobites, the beautiful crinoidea, chain corals, and favosites, compose a zoological suite, altogether unlike what now exists, a strange and antique order of beings adapted to the primeval deep.

If we estimate the relative periods which intervened between the deposition of any given rocks by the variety and thickness of marine strata which separate them, we shall find that in proportion to the distance of the strata from each other, in proportion to the difference of their ages, is the difference of their zoological contents. Thus the fossils of the mountain limestone are more different from those of the lias than from those of the magnesian limestone. The lias fossils are wholly different from those in the chalk, but partially similar to those in the Bath oolites.

M. Deshayes' results.

The principle that the difference of the forms of ancient organic life from those of existing nature is directly proportionate to the difference of the epochs of their existence, has been put to a severe and curious test by one of the best conchologists of France, M. Deshayes. Passing over the primary and secondary rocks, in which no plant or animal has yet been found identical with a living species, he analyzes the tertiary fossils according to their relative antiquity, and obtains the remarkable result, that the lowest and oldest of the tertiary strata contain three and a quarter per cent. of species identical with living types; that a second and less ancient group of these strata holds eighteen per cent. of such analogues, a third more recent group forty-nine per cent.; and the most recent of all these deposits contains little else than modern species. When we recollect that all these strata are of a date probably anterior to the creation of man and the present races of quadrupeds, the results of M. Deshayes' investigation must be considered as highly valuable data towards forming a just notion of the great antiquity of the stratified rocks, the long periods passed through in their production, and in the accompanying changes of organic life, the gradual nature of these changes, and the correspondence of the *General System* of Nature at all epochs, even amidst the greatest particular diversity.

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Some fossils appear to have been in existence only during the deposit of one particular stratum, as for example, certain productæ, spiriferae, trilobites, in the mountain limestone; axinus obscurus, in the magnesian limestone; ammonites Bucklandi, gryphaea incurva, in the lias; ammonites callovicensis in the Kelloway rock; hamites of many kinds in the Gault; unanchytes, spatangi, belemnites mucronatus, in the chalk; rostellaria macrop-tera in the London clay; fusus contrarius in the crag. These are said to be *characteristic fossils of the strata*, and, in general, very great importance is justly attached to their recognition; but no Geologist should permit himself to trust to them exclusively, for they are not *always and invariably* present, and he may be often called upon to fix the date of a rock by the help of other witnesses. Many fossils are found in more than one rock, and the number of these will probably be much increased by further inquiry. Thus in the South of England, plagiostoma giganteum occurs in the lias and inferior oolite, terebratula intermedia belongs to the great oolite and cornbrash, pecten lens is found in the cornbrash, Kelloway, and coralline oolite, astacus rostratus and spatangus ovalis range through the Kelloway rock, calcareous grit and coralline oolite of Yorkshire; and mya literata appears in nearly the whole range of conchiferous strata from the marlstone to the coralline oolite inclusive.

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Character-  
istic fossils.

These facts entirely overthrow the notion favoured by some Geologists that each rock contains the relics of a distinct creation of animals. They prove, on the contrary, that the changes were not sudden but gradual; and suggest the hope that hereafter, when the laws of the *distribution and transference of the existing marine races* shall be better understood, and the history of the fossil species more complete, the phenomenon may be satisfactorily explained in accordance with the recognised laws of Nature, "constant in her ceaseless change."

It is generally observed that where the series of strata is complete, they are softened as it were *off* into another by an admixture or alternation of ingredients. Thus, for instance, in Somersetshire, the new red marl and lower lias clays are sometimes softened into one another; and in Yorkshire, the Kelloway rock, Oxford clay, lower calcareous grit, coralline oolite, upper calcareous grit, and Kimmeridge clay are so blended at their junctions as to render it difficult to draw any hard line of separation. In such cases it commonly happens that several fossils of the lower rock are continued into the next above, and thus the zoological change is as gradual as the mineralogical one. On the contrary, when two strata are separated by a hard and decided line, as, for instance, the coralline oolite and Kimmeridge clay near Oxford, we shall generally be justified in suspecting that the lower stratum is imperfect, in consequence of the removal of its upper beds before the next stratum covered it. In this case the zoological contrast between the two rocks is as decided as the mineralogical one, and keeping in view the Linnaean adage, *Natura non facit saltus*, we should be on the look out for some intermediate beds in other places. Such are described near Weymouth, by Sedgwick; and in Yorkshire, have been named the upper calcareous grit.

Gradations  
of deposits  
and of fossils  
coincident.

The chalk in England contrasts so entirely with the tertiary formations above, that we naturally expect to find in some other Country beds of intermediate character to connect them. These are found at Maestricht, where a sub-cretaceous, granular rock, intermediate in

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composition between chalk and calcaire grossier, contains many fossils of the chalk, and several which strongly resemble those of the tertiary group.

The researches of Sedgwick and Murchison in the Eastern Alps, have brought to light the remarkable Gosau beds, which, by these Geologists, are thought to be of the same intermediate era.

Probably more complete researches on this point will make known a greater number of such intermediate strata, soften the contrasts between contiguous rocks, and fill up all the blanks in the harmonious system of gradually changing marine deposits, characterised by corresponding transformations of marine exuvie.

Terrestrial  
animals  
and plants.

The remains of TERRESTRIAL ANIMALS embosomed in the Earth are very few, and those of plants bear so inconsiderable a proportion to the Flora of the present age of the World, as to give us much less information concerning the ancient state of the land, than the marine exuvie afford of the former condition of the sea.

But as far as they go they confirm in the most satisfactory manner the conclusions drawn from the consideration of marine remains, of the succession of systems of organic nature. The plants which sometimes alternate with, and which overlie in immense variety and abundance, the mountain limestone, are a group eminently distinguishable from those which belong to the oolitic coal beds. In the former deposit, lepidodendra, sigillariæ,

stigmatiæ; in the latter, cycadææ and zamizæ; and the plants of the strata above the chalk are still of a different type.

It would thus appear that the same systems of calcareous rocks which contain the most remarkably different suites of zoological remains, likewise enclose in the alternating beds of sandstone and shale plants equally distinct.

As amongst the marine, so amongst the terrestrial remains, those most decidedly unlike the modern productions of Nature belong to the most ancient deposits. In the intermediate portion of strata the discrepancy diminishes, and in the most recent rocks, the plants strongly assimilate to the genera and even species which now cover the surface.

We might here examine the conditions of the land and sea as to climate during the several epochs of organic existence, a subject of the greatest curiosity and interest, and for which an immense mass of materials is already collected; but this investigation requires the statement of details which cannot be here with propriety introduced. We must, therefore, postpone the discussion till we come to treat of the strata and their contents in the order of their successive deposition.

We shall then also enter into the history of the freshwater formations which locally diversify the great mass of marine deposits, and contribute to elucidate the character of the ancient land and streams.

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## CHAPTER II.

### DESCRIPTION OF THE SERIES OF AQUEOUS DEPOSITS WITH THEIR IMBEDDED ORGANIC REMAINS.

#### *Series of Aqueous Deposits.*

General  
basis of  
Plutonic  
rocks.

HAVING now stated general principles, useful alike to the Geologist who investigates in the field, and to the student who reads in his closet, we proceed to describe the successive systems of aqueous deposits, beginning with the lowest of all, viz. those which rest upon granite and other crystallized and unstratified rocks. That there is such a basis of crystallized rocks beneath all the strata, in all Countries, cutting off and limiting our observations, and hiding whatever wonders are concealed below, is now universally admitted. The subjacent position of granite is so fully established by observation, that even when portions of it are clearly seen to be laid upon stratified rocks, no doubt is entertained of its having been in every case ejected from its true source below all the strata. But the same observations, which so clearly establish this important law, as certainly overthrow the dogma, once held incontrovertible, that granite is always the oldest of known rocks. They prove to a certainty that granite is of all ages, or, more properly speaking, that its production has really no relation of age to the deposition of any particular set of aqueous strata; but that it has been produced by agencies entirely independent of them, and only locally, and in one sense accidentally, brought into juxtaposition with them. This interesting discovery, from which we learn that the production of granite below the stratified rocks has been continued, perhaps without intermission, during the whole period of the accumulation of the strata, has greatly changed and improved our concep-

tions of the whole system of Geology, and is probably destined to clear still more the horizon of this Science. But we must be careful not to be allured by this new light too far from those inferences concerning the age of granite which it so properly qualifies. It does not follow, because some granite is more recent than chalk, that therefore all granite is more recent than gneiss and mica slate. It does not follow, because when in contact with granite veins gneiss may sometimes assume perhaps more than even its usual granitoid aspect, that therefore granite is merely fused gneiss, that gneiss and slate are incipient granite, and that common sandstone may in time become gneiss.

But it does follow, as a matter of high probability, independent of further observation, that because granite has been formed at several periods during the deposition of strata, by agencies excited far beneath and independent of them; and because, in some instances fragments, and universally the disintegrated ingredients of granite, lie in the oldest strata, that the production of this rock was in progress before any of the strata were deposited; whether those strata now rest upon that old granite or have been forced by subsequent convulsions into contact with newer portions of the same kind of rock.

Whatever theory on the original formation of granite we choose to adopt, it must be allowed that the igneous action to which it owes its birth preceded the aqueous, which accumulated the lowest strata now observable.

This being admitted, two points of inquiry suggest themselves with respect to the age of the strata which have been called primary. First, are those strata really

Primary  
strata



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the altered deposits of one long period of aqueous action prior to all the secondary and tertiary strata, or have many repetitions of igneous action *primarized*, to use Mr. Conybeare's remarkable expression, strata of all ages, secondary and tertiary, which happened to be the lowest at the points of action? Secondly, may we believe, as the title of primary seems to imply, that these are the oldest of all the strata, the first that were laid by water upon the consolidated igneous crust of the Globe? That these questions should be put at all will probably appear very surprising to those who have drawn all their notions on the subject from books of some date, without attending to the rapid progress of geological opinions.

not to be  
known only  
by mineral  
characters,

On the first question we may remark, that it must be allowed that subterranean heat, operating chiefly by the ejection of melted Plutonic rocks, has transformed to a certain degree and limited extent, strata of all ages which were exposed to this action, and thus made the lias shale of Savoy, for example, approximate to the character of clay slate. In such cases, there can be no objection, we conceive, on the part of any Geologist to apply the same term to this *change* of the rock, which we may think fit to employ when treating of the analogous *change* presumed upon very good grounds to have affected in more ancient times the strata called primary. We may, therefore, adopt at once Mr. Lyell's term of *metamorphic*, and designate by it all those parts of certain aqueous strata which have been transformed in structure or appearance by subterranean heat applied since their deposition. All strata then may become metamorphic under given conditions, and may assume, locally, some of those appearances which belong, perhaps universally, to the primary strata; but are we, therefore, to deny the antiquity of these latter? or to group all such metamorphic strata together as of indefinite age, and merely characterised by proximity to igneous rocks? Surely nothing could be more in contradiction with the principle of classification of strata, the relative antiquity of their deposition. We cannot, therefore, agree to the term *hypogene* of Mr. Lyell as applied both to granite and the strata usually called primary. When applied to granite it is synonymous with, and may perhaps be preferred to Plutonic; when applied to stratified rocks its meaning is better conveyed by the term metamorphic, which we shall apply to those portions of all strata, without regard to their age, which are in the altered condition implied.

but by their  
position.

The true conclusion on the subject of the first inquiry then appears, to be, that we are not to assume strata to be of the primary age merely because they appear to have undergone certain changes, analogous to those which gneiss or clay slate have sustained; but we must determine their age by the very same methods as we use in any other case of stratified rocks, viz. by examination of their position relatively to other strata, their organic remains, and their original mineral composition and structure. Examined in this way, there can be no doubt, we conceive, that the use of the term primary as applied to the gneiss, mica slate, and clay slate systems generally, defining them as a certain mass of strata anterior to the secondary and tertiary rocks, is perfectly correct, because in all Countries where these rocks occur together, the inferiority of their position is well proved; and they have those general analogies of original composition, and those relations to organic remains, which would be satisfactory evidence in every other case. Those who reject the term primary, and

yet retain the use of secondary and tertiary, have constructed a series wanting its first term.

The answer to the second inquiry cannot, perhaps, in the present state of knowledge on the subject, be given with the confidence of assured impartiality. It certainly does not follow that because gneiss, for example, is generally allowed to be the lowest of the stratified groups which we can trace, that there may not be other strata of a totally different nature below it, partially or wholly concealed by Plutonic rocks, still less is it evident that such strata may not have existed, and been subsequently absorbed into the general mass of igneous rocks below. Geologists of eminence appear to think that granite itself is a derivative igneous, from an earlier stratified rock; and that as gneiss is certainly in some respects to be compared to partially fused sandstone, so it may be supposed that while, above, the mass of strata was augmented by additions from water, it was diminished, below, by the transforming action of heat.

Strange as this notion may appear we certainly are not at present in possession of facts sufficient to wholly disprove it. But neither are there any facts to raise it above the rank of a general speculation grounded on particular and local alterations of stratified rocks. It cannot, therefore, be admitted for want of sufficient evidence, and, perhaps, the following considerations will justify us in rejecting it. Many of the primary strata undoubtedly are derived from the disintegration of preexistent granitic rocks. The character of the organic remains in these strata is in general so remarkably contrasted with those which at present exist, that, joined to the diminution and final extinction of their numbers as we descend in the series, and the almost perfect identity of their characters over immense geographical areas, we seem really to behold in them the first terms of organization, the earliest records of the establishment of life upon the consolidated crust which overspread the fused matter within the Globe.

However, without plunging further into premature speculations of this nature, we shall content ourselves with the admitted conclusions.

Conclusions  
admitted.

1. That there is a sequence of age to be traced through all the stratified rocks, which may, therefore, be very justly grouped in any suitable number of successive divisions, as primary, secondary, and tertiary, and that these terms, if convenient, are not improper.

2. That the series of stratified deposits, whether we know their first terms or not, were laid upon a general basis or floor of Plutonic rocks.

3. That the term primitive, whether applied to igneous or to aqueous deposits, must be abandoned, as affirming what is not, and perhaps cannot be proved.

4. The alteration of strata by general igneous agency, or by the local contact of melted rocks, being an effect wholly independent, both as to cause and period, of the deposition of strata, must be treated in connection with the other effects of subterranean heat.

Governed by these considerations, the succeeding part of the Treatise will form two clearly marked divisions: 1st, the description of the products and operations of water through all geological periods to the present time; and 2d, a similar account of the products and operations of heat.

Exceptions to this rule will occasionally occur where it is necessary to notice the changes produced by igneous

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Are primary  
strata the earliest  
deposits  
from water?



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ous agency in the condition of the bed of the sea, and other circumstances which influenced the character and extent of the aqueous deposits.

In the following description of strata, we shall retain the general titles of Primary, Secondary, and Tertiary Strata, and divide them into several systems according to certain properties, or in agreement with their elective associations. The reasons which have determined the mode of arrangement in each case will appear in the history of the several systems.

#### PRIMARY STRATA.

##### *System of Gneiss and Mica Schist.*

These strata, derived probably from decomposed granitic rocks, with several subordinate and associated strata, all devoid of organic remains, constitute, according to the concurring testimony of geological observers, the lowest group of the whole series of Neptunian deposits. From the effects of heat upon these rocks, their natural analogy to granite is sometimes so much heightened, as to cause some uncertainty in distinguishing between them. The rocks of this whole series might without impropriety be termed *granitoid strata*. They are usually called primary, sometimes primitive strata. We use the former term in the same sense nearly as that in which M. Omalius d'Halloy employs the title primordial, and intend that it shall be understood to include the following system.

##### *System of Argillaceous Slate.*

In this argillaceous series, which includes the whole mass of the slate rocks of England and Wales, lie the most ancient organic remains yet discovered. The calcareous slates of Caermarthenshire, the black limestones of Norway, the shelly limestones of Shropshire, Dudley, and the Eifel, belong to this division, which is generally known by the term of transition strata; a title which is found convenient, but considered by many modern writers too theoretical to be often employed with propriety. We shall chiefly employ it to designate the limestones of this period.

#### SECONDARY STRATA

as they occur in Europe. It is probable that other modes of arrangement will be found necessary for other regions.

##### *System of Carboniferous Strata.*

Containing a very large series of sandstones, limestones, shales, coal, and ironstone, with abundance of marine exuvie in the calcareous portions, and a profusion of terrestrial plants in connection with the coal. The lower part of the system consists principally of red sandstone, the middle of limestone, the upper of coal shales and sandstones. The limestone has been long known in England by the name of mountain limestone.

##### *System of Saliferous Strata.*

We have chosen this title, because rock salt is exclusively found in these strata in England, and is especially abundant therein throughout Europe. This remarkable mineral is, however, found, though not in Britain, in several other parts of the series of secondary strata.

Red and white sandstones with red, white, and blue clays, gypsum and rock salt, constitute the mass of this system; and locally enclose two principal calcareous

rocks, the lower one usually charged with carbonate of magnesia, the upper one a shelly limestone not known to occur in England.

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##### *System of Oolitic Strata.*

Consisting in England of several distinct groups of calcareous rocks, alternating with clays and sandstones which are often calcareous, the whole remarkably rich in marine exuvie, with local interpolations of terrestrial plants and coal deposits, and one estuary formation.

The lowest limestone group is usually argillaceous, the others are mostly nearly pure carbonate of lime, and very generally oolitic. On the Continent many of the minute distinctions of these rocks disappear.

##### *System of Cretaceous Strata.*

Chalk with argillaceous marls and layers of nodular flint, form the most remarkable part of this system, and it graduates below to green, grey, and ferruginous sands, with layers of nodular schist, rich in organic remains.

#### TERTIARY STRATA.

These form, properly speaking, only one great and various system of sands, clays, and coarse limestones, stored with great numbers of marine exuvie always very analogous to, and in the most recent group identical with existing species, locally interstratified with freshwater deposits of marls, limestones, and gypsum.

Above all these systems of strata lies a variety of tumultuary deposits apparently produced by violent action of moving water during and subsequent to the elevation of the tertiary strata, and enclosing in abundance the remains of extinct quadrupeds. These are termed *Diluvial Deposits*.

Lastly, we have the products of modern rivers, lakes, and tides, or generally, the deposits, whether chemical or mechanical, which have been effected by water acting as it now acts, and where it has acted, since the last great revolutions by which the relative level of land and sea has been changed. These are called *Alluvial Deposits*.

##### *Range of the Primary Strata.*

At all periods in the history of Geology, persons of enlarged views have passed over the limited areas of particular Islands and Kingdoms and have sought to connect the results of their local inquiries with those drawn from similar researches elsewhere. In this point of view the long chains and insulated groups of mountains become of the highest interest. These lofty peaks on which the snow rests for ever, whose rocks contain no vestiges of life, may be imagined to have stood up in ancient times above the level of the waters, dividing the primeval deep into seas very different from those which now branch off from the Ocean. And though this supposition is probably inaccurate, though modern researches render it extremely credible, that in fact the mountain ranges, far from limiting the ancient sea, and altering the nature of its deposits, were really raised out of its depths at periods comparatively recent, this does not diminish their geological importance. For if by means of this uplifting we are made acquainted with some of the materials which would otherwise have been concealed from the eye of Philosophy, these mountain ranges must be studied as the basis of the whole system of Geology.

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They form, so to speak, the skeleton of the Earth, and are the marking features of its topography; their insulated groups characterise Kingdoms, their long connected chains divide the races of mankind, and define the geographical limits of the distribution of land animals. To the Geologist they have become still more interesting in consequence of a remarkable general law of their physical structure. For in all climates of the Earth, under every conceivable variation of external circumstances, the principal ranges of mountains are everywhere composed of similar rocks, and those originally the lowest, and in part at least the oldest, with which we are acquainted. By what violence from below they have been uplifted to their present heights, so as to break through and rise from beneath the strata which were superimposed upon them in succession, is a capital question in Geology.

These rocks are the primary strata of gneiss, mica schist, slate, and their many associated strata, the deposits of water, resting upon and often pierced by granite and other crystallized compounds from fusion. An outline of the mountain groups and chains which diversify the face of our Planet, seems, therefore, the best foundation for a systematic view of the strata which rest against these rocky barriers.

Relations of  
mountain  
ranges and  
groups.

It has long been the fashion to attempt to establish certain geometrical relations among the chains of mountains, to refer them to particular parallels and predominant directions, but this labour, unconnected with Geological researches, seems to have been very fruitless. Perhaps it would be more correct to say the essence of the geographical relations amongst mountains is irregularity. For though we speak of long-continued chains and belts of mountains, it is very certain, in fact, that to be assembled in groups is the real character of mountain association, and that the chains and belts are nothing but approximated groups. A Geological Map is in this respect a most valuable instructor; from it we see that, instead of the plains being insulated among the mountains, instead of the upper strata appearing in small contracted patches like oases in a desert, they spread wide, and flow round the bases of the mountains, as the Ocean encircles the islands and continents.

Among the few general remarks on this subject we may observe, that the most insulated and many of the loftiest eminences on the surface of the Earth are the volcanic summits; the most connected ranges of uniformly high ground are formed by the secondary limestones. Finally, that the general outline of Countries is much influenced by the direction of their interior mountains.

European  
basin.

The Scandinavian chain, commencing at the North Cape, runs parallel to the coast of Norway, and gives off branches to the East which pass round the Gulf of Bothnia. The line of the Scandinavian chain may be imagined to cross the sea to Zetland, and from thence to proceed by the Helvidian Isles and the North-Western half of Scotland to Ireland, where it is much broken into separate groups in the North, South-East, and South-West of the island. The Isle of Man, the South-Western part of Scotland, the Cumbrian group, the broken mountains of Wales, and those of Devon and Cornwall, are so many separate protuberances of the exterior rocks of the Earth, which, with Bretagne and the North of Spain, compose the interrupted Western border of Europe.

The Pyrenees, ranging to the East, may be considered

as carrying on the primary range toward the Alps, which hold so long a course from the shores of the Mediterranean in a winding direction to the Danube, and seem to prolong themselves in the inferior ridges of the Carpathians toward the Black Sea and the Caucasus. If, now, we consider Caucasus as continuing the Alpine line round the Caspian Sea to the lofty Paropamisian and Gaur mountains, and from thence turn Northward along the summit of drainage including the Sea of Azof, we come to the Uralian chain, which leads us to Nova Zembla, and thus we find nearly all Europe, and a considerable tract in Asia, enclosed within this irregular circle of primary mountain groups; and it may often hereafter be convenient to speak of this space as the European Basin. It is within this region that the greatest variety of stratification has been observed.

Within this area are the primary elevations of the centre of France, the Ardennes, the Vosges, the Black Forest, the Thuringerwald, the Hartz, and the Bohemian Circle; South of it are the Sierras of the Spanish peninsula, Corsica, Sardinia, the Apennines, the Dalmatian ridges, and the mountains of Greece and Mount Hæmus.

The mountains of Africa are long, unconnected ranges. Atlas borders the Northern shore, a range parallel to the Equator determines the course of the Niger, and, perhaps, the prolongation of it defines the drainage of the Nile. The high land about the Cape runs in various directions.

Another basin of about equal extent, but more perfectly defined in its boundaries, and more uniform in its interior composition, is that great Siberian tract which lies to the East of the Uralian, and to the North of the Altaian, Yablonoy, Stanovoy, and Kamschatdajé mountains. The vast Empire of China and Tartary lying to the South of the Siberian basin, and to the North of the Indian Empires, may be considered as a third great but divided basin between the Himala and Altai heights.

The peninsular Indian regions, with their islands stretching toward New Holland, Persia, Arabia, derive their features from considerable primary mountains directed more parallel to the circles of longitude; the Southern part of Africa is similarly defined by the long ridges of mountains which run from Cape Guardafui in the East, and above the sources of the Congo on the West, to converge about the Cape of Good Hope; while the greatest breadth of this peninsulated continent, from Cape Verde to Cape Guardafui, is coincident with the high mountains of Kong, Donga, and Southern Abyssinia, and the North-Western projection is caused by the elevated Atlas.

The interrupted system of primary mountains which extends from the Pyrenees to Behring's Straits may be supposed to continue in the long and magnificent Cordillera parallel to the whole Western coasts of America, while the North-Eastern shore is parallel to the Alleghany and its Northern connections, and between these and the Western Cordillera, the vast basin of the Mississippi pours its waters into the Gulf of Mexico. The Eastern projections of the coast of South America, which is in a certain degree correspondent to that of Africa, are owing to lateral extensions from the great Western Cordillera.

Though the above enumeration and classification of mountains be extremely imperfect and subject to many objections, it answers the purpose intended, which was to show that the leading features of our continents, their geographical extent and connections, are dependent on

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the lines of mountainous land, and as these are constituted of the lowest and oldest stratified resting on granitic rocks, it generally happens, as Mitchell foresaw, that in every Country the secondary strata are arranged with reference to the lines of mountains.

Elie de  
Beaumont's  
Theory.

An entirely new kind of interest has lately been given to this subject in consequence of the researches of an eminent foreign Geologist. Elie de Beaumont, from considerations of some observed accordances between the direction of mountain chains and the geological era of their uplifting, has advanced the hypothesis that these two circumstances are always mutually dependent; and, in consequence, supposes that all ranges of mountains which were uplifted at the same period are parallel to one and the same great circle on the sphere. This is not the place to examine this curious question as fully as it deserves, and we shall, therefore, only mention some of the cases in which this ingenious Geologist supposes that the truth of his doctrine may be recognised.

If a great circle be conceived to pass round the Earth through Natchez and the mouth of the Persian Gulf, and the directions of mountain chains be compared with it, it will appear that the Pyrenees, part of the Apennines, the Dalmatian and Croatian ranges, and part of the Carpathians, are parallel to it. Now in accordance with some researches of Geologists, M. de Beaumont supposes that all these mountain chains were thrown up at the same geological epoch. Nearly parallel to the same circle are the Alleghanies of North America, the Gats of India, and the Paropamisian heights; but further information must be acquired before we can be asked to admit that these mountains may have been thrown up at the same epoch.

Another circle may be traced on the sphere parallel to the Alps, from the Valais to Styria, and to this system we may refer the Atlas, the Caucasus, the Balkan, the Himala, &c.; and, according to the hypothesis of M. de Beaumont, these must have been all raised at so late a period as since the deposit of the tertiary strata. This subject will again attract our attention.

#### *Gneiss and Mica Schist System.*

Principal  
rocks of the  
gneiss and  
mica schist  
system

This consists principally of the two following rocks:

*Gneiss*, a rock composed of the same mineral ingredients as granite, but laminated and stratified;

*Mica schist*, composed generally of quartz and mica, in alternate layers.

With these are associated, and often intermixed,

*Quartz rock*, generally appearing like a semi-crystalline or imperfectly granular mass of quartz, variously modified by small interspersed quantities of mica, felspar, &c., sometimes more compact, and resembling the quartz of veins, in other examples mixed with clay slate.

*Crystallized limestone* mostly granular.

*Serpentine*, a magnesian rock generally distinguishable by its softness, smoothness, and bright mottled colours.

*Steatite*, a still softer and smoother rock than serpentine, generally of whiter colour.

*Polstone*, a soft, often grey or greenish magnesian rock.

*Hornblende schist*, a laminated rock of hornblende, variously modified by felspar, mica, and chlorite, generally in alternate laminae.

*Chlorite schist*, a rock almost precisely similar to mica schist, with the exception of the difference between chlorite and mica. It is subject to the same contortions as mica schist, and passes like it by insensible gradations to gneiss and clay slate.

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*Talc schist*, mentioned by McCulloch, is another of the fissile rocks which differ from mica schist only by the substitution of one mineral for another. It is rare.

With respect to the order in which they succeed one another, nothing very definite can be advanced. The greater number of observations concur in assigning to gneiss the lowest place in the system, a conclusion supported by its evident analogy to granite, and in the same general way we may, perhaps, place quartz rock and chlorite schist in the upper part of this system, and next to the clay slate, with which, indeed, they are often associated. Limestone and serpentine are so irregular and peculiar in their occurrence, that though, perhaps, their era is more definite than that of any other of these rocks, they can scarcely be employed to mark a geological date. In some district or other nearly all these ancient rocks alternate with one another so variously and unequally, that what would be called the oldest rock in one region may be the youngest in another, and, therefore, it is no wonder if the attempts which have been made to divide the gneiss and mica schist system into several distinct formations, have wholly failed. It is not till zoological evidence is brought to bear on the subject that we are able to demonstrate completely the relative age of strata, by distinguishing different deposits and different ages of the same kind of rock.

That the materials of the mechanically aggregated gneiss rocks, of the whole series of strata, in fact, except the calcareous rocks, are derived from the disintegration of more ancient granite and other crystallized compounds, is an opinion which is strongly impressed upon every Geologist while examining the composition of gneiss.

The ingredients of gneiss and granite are the same, quartz, felspar, and mica; they are mixed with the like accidents and permutations, and occasional admixture of other minerals, and are subject in both to the same extreme variation of size. But these rocks differ in the most essential point of view under which they can be compared, viz. the mode of arrangement among their constituent masses. The ingredients of granite are so connected together by contemporaneous, or nearly contemporaneous crystallization, that one substance penetrates and is united into another, and we are compelled to conclude that they were accumulated together, not in distinct pieces ready formed, but that they actually never had a separate existence as solids until their different properties were developed by crystallization from a fused mass.

On the contrary, gneiss well characterised shows evidently, by some degree of wearing of the edges and angles of the quartz and felspar, and much more decidedly by the laminar arrangement of the mica, and consequent minute stratification of the rock, that its materials, ready made and crystallized, were brought together and arranged by some mechanical agent, principally influenced by gravitation, in fact by water. Could any doubt remain on this subject after a sufficient examination of gneiss strata, in all their gradations from a rock resembling granite to a fine grained fissile mass, hardly distinguishable from clay slate, it would be at once removed by comparing them with a suite of sandstones, many of which, like gneiss, are composed of granitic debris and strongly allied to it in structure, but most evidently aggregated by water.

In a great majority of instances, gneiss rocks immediately follow granite; being then composed of the materials of that rock which had suffered the least degree

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of waste and abrasion, it is no wonder that on several occasions it should strongly resemble its parent. And if we allow, what may probably be true, that the heat of the granitic nucleus was then sufficient in some places materially to affect the consolidation of the strata on the bed of the sea, we shall perceive another cause why the most ancient mechanical strata approach in character to the Plutonic rocks.

Though the disintegrated *materials* of granite compose almost universally the substance of gneiss, *fragments* of granite are most rarely discovered in it. This circumstance, combined with its numerous laminae and crystalline aspect, seems to indicate that the aggregation of gneiss happened without any great degree of turbulence or lateral motion in the water. It may, perhaps, lead us to suppose that in those early periods the fluctuating temperature of the bed of the sea contributed sometimes to accelerate the aqueous decomposition of the granite, and afterwards at intervals to harden its stratified materials into gneiss.

Stratification of gneiss.

Gneiss beds are of extremely various thickness; and the laminae of which they consist are subject to such extraordinary curvatures, that it is often very difficult to trace them.

Where other rocks alternate with gneiss, as hornblende slate or mica slate, the stratification is rendered very evident, but otherwise the beds are less regular, and are often discontinuous, as in micaceous sandstones and in argillaceous slates.

The contortions of the laminae of gneiss are observed to be most numerous and surprising, where, as frequently happens, veins of granite, quartz, or felspar divide this rock. These veins cross the laminae at various angles, and generally cause some peculiar twists along their sides; they not unfrequently insinuate themselves between the laminae, and in this case, when thick and extensive, may be mistaken for alternating strata. It is probable that many cases of supposed alternation between gneiss and granite may be thus explained, and that in other cases the rock called granite may be really a coarsely granular gneiss, whose particles have been very little moved by water, or unusually affected by subsequent application of heat.

Minerals.

Gneiss being one of the most extensive stratified rocks is a rich repository of minerals, both in the New and the Old World. Garnets frequently, zircon, beryl, disthene, epidote, tourmaline, rutile, oxide of tin, oxide of iron, sulphuret of molybdena, more rarely, are disseminated in its laminae. The veins of quartz, calcareous spar, carbonate of iron, and sulphate of barytes, which divide it, contain the sulphurets of lead, copper, and zinc, native silver, tin, &c. (Brazil, Humboldt.) and many other minerals occur in the calcareous strata which alternate with or are enveloped by the strata of gneiss.

Rocks associated with gneiss.

Gneiss alternates with granite in the Reisingebirge and in Quito, and in some cases graduates into the character of granite, as on the Southern declivity of the Titlis and Jungfrau; (Humboldt;) more frequently it exchanges beds with mica schist, hornblende schist, and granular limestone and clay slate. These rocks are sometimes in such small quantity as merely to mark lines of division in the mass of gneiss, but at other times they swell out to great thickness. The limestone beds in particular are remarkably local and irregular in their occurrence, and instead of extending, like the more recent calcareous strata, through large tracts of country, appear in the form of large lenticular masses, enveloped

on every side by the predominant rocks of gneiss. The term *subordinate*, on a great scale, is not improperly applied to these lenticular rocks, though in local Geology, their occasional great extent and comparative regularity may entitle them to be classed under an independent title. Thus Charpentier arranges the granular limestone of the Pyrenees.

By the substitution of hornblende for mica, gneiss gradually changes to hornblende schist; the loss of its felspar approximates it to mica schist, the diminution of its mica produces the resemblance of quartz rock. A finely granular state, with more evidence than usually appears of watery friction among the particles, almost transforms gneiss to sandstone; a more minute admixture of its ingredients, with a predominance of chlorite, gives it the aspect of argillaceous slate. In all these cases great caution is required, and its geological relations should always be consulted before deciding on the name of this Protean rock. These gradations happen most frequently at the junctions and alternations of the several rocks.

Mica schist, like gneiss, appears to have derived its ingredients from the destruction of granitic rocks; but it generally contains but little felspar. May we conjecture that this mineral, which is easily acted on by ordinary agents, was itself decomposed during the disintegration of the granite, and mostly dissolved, leaving the quartz and the mica to be arranged by the water in the alternate layers which render this rock so remarkable?

Mica schist.  
Its origin.

The lamination of this rock is subject to much unevenness, in consequence of the irregular size and arrangement of the pieces of quartz, and the undulations thus occasioned on the micaceous surfaces, are often further modified by interspersed garnets. Besides this minute inequality, the laminae of mica slate are liable to the same contortions and curvatures as those of gneiss; the same difficulty often occurs in tracing its beds, similar and very numerous veins of quartz traverse and mingle with its layers, and when in contact with granite it is locally penetrated by similar granite veins.

Various minerals are similarly disseminated through it, as garnet, emerald, beryl, disthene, tourmaline, felspar, epidote, hornblende, columbium, molybdena, rutile, oxide of tin, wolfram, oxide of iron, grey cobalt, native gold. Its metallic veins are of the same nature as those in gneiss; it alternates in the same way with quartz rock and the other slates, and encloses similar deposits of limestones. It seems, therefore, almost superfluous to say, that the line of rigid distinction between the mica schist and gneiss can only be drawn in the closet. Yet, in fact, on a great scale the two rocks retain their typical characters over large tracts of country, and must be considered apart.

Minerals.

Quartz rock, in the greater number of instances, seems a more recent deposit than mica schist and gneiss, though indeed, by an easy change of its composition, it becomes nearly identical with them. This circumstance, combined with the internal evidence of texture, seems to decide the question of the origin of quartz rock, and to prove that, however altered by subsequent igneous action, it is originally a Neptunian and mechanical deposit. The degree of compactness which it exhibits varies through a large range, in some cases approaching the loose granular character of sandstone, in others the density of the quartz of veins. In this latter case it seems that the mass is composed of fragments so firmly

Quartz rock.

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united as to suggest the idea of their having been fused together since their deposition from water. Perhaps, also, in some cases, what has been considered as quartz rock may be really an expanded or overlying vein.

Minerals.

In South America this rock is the repository of many rich ores and metals. Native gold is found in Brazil in a stratified rock of quartz, and micaceous iron ore, which is suspected by M. Eschwege to be the original repository of diamonds, and appears to be intimately related to quartz rock. The flexible quartz of the same country is a granular rock with drusy cavities containing topaz and amethyst. (Brongniart.)

Crystalline  
limestone.  
its origin.

Crystalline limestone is in general observed to be stratified, frequently to alternate with gneiss and mica schist, and is therefore a Neptunian deposit. Its frequent high state of granular or saccharoid crystallization may perhaps be due to changes operated since its deposition, and partly occasioned by the action of subterranean heat, of course more sensible in the lower than in the upper calcareous deposits.

It is difficult to imagine that such a rock could be formed by crystallization from water, often in laminae exceedingly thin and regular, and alternating with evidently mechanical deposits. That the calcareous matter of many rocks, at first precipitated in sediment, has been since arranged in crystalline and concretionary masses, is certain. Thus the oolitic structure, thus the crystalline cement of the Lincolnshire oolites, has been occasioned. These effects, it is now known from artificial trials and from observations in Nature, are more decisive when heat and pressure operate upon the particles. By this combination, the earthy sediment of chalk is condensed into crystalline limestone.

The deposits of crystalline limestone, whether distinctly stratified or not, are in general detached and limited, and so entirely enveloped in the strata of gneiss and mica slate, as to compose but a subordinate member of those extended formations. This fact appears to indicate that in the earliest periods of Neptunian operations, the precipitation of calcareous matter was occasioned by agencies of a more local and limited nature than those which produced the broad strata of lias, oolite, and chalk.

May we imagine that the accumulation of these nodular or lenticular masses was determined by local developements of subterranean heat, which directly, by change of temperature, or by intermediate chemical agencies, might render the calcareous matter insoluble? However we may seek to explain it, the fact is undoubted, that during the aggregation of the gneiss and mica slate systems, a large quantity of calcareous sediment was deposited, not in one uniformly extended stratum, but at scattered points, and in unequal quantity. And this irregularity of deposition continues to be observed in an inferior degree in the limestones of the clay slate system, which are often lenticular, but above this point, when the influence of the internal heat must be supposed less intense and more equally diffused, the calcareous strata become at once more abundant, more regular, and more uniformly extensive.

Minerals.

Though primary limestone be, in fact, a simple rock, its aspect admits of many variations from the unequal admixture of other mineral substances. Of these the most frequent are mica, talc, and steatite, the latter of which often communicates a green or mottled colour to the whole rock. Crystals of argite, (Tise,) garnets, and felspar, (Col. de Bonhomme,) occur in it in some

places, and tremolite and argillaceous slate lie upon its laminae. It sometimes assumes a brecciated character, as if composed of limestone fragments, and more rarely contains fragments of rocks of the gneiss and mica slate system.

It is the fruitful source of statuary and architectural marble, contains a great variety of minerals, and is locally traversed by veins of quartz, felspar, and granite, and by veins of cobalt, galena, iron.

The limestone associated with gneiss and mica slate is usually, perhaps always, destitute of organic remains; while part of that associated with clay slate almost invariably contains shells, trilobites, or corals. The gneiss and mica system may therefore be considered as *hypozoic*, or beneath the strata which contain reliques of life; while the clay slate system is clearly *epizoic*, or within the zoological era. But this distinction, when applied to such vast thicknesses of rock devoid of these remains, and variously alternating, is rather doctrinal than practical, and being founded solely on a comparison of the calcareous strata, we shall so restrict any use which we may find it convenient to make of these terms. They are besides theoretical terms; for if we suppose the crystalline limestones devoid of organic remains, to have derived their peculiar texture from changes subsequent to their deposition, under the influence of subterranean heat, it is possible that the absence of organic remains may be often a consequence of this change. This is possible; at the same time it must be owned, that circumstances hereafter to be mentioned concerning the limestones of the slate system above, appear strongly confirmatory of the hypothesis which these terms involve.

Contains no  
organic  
remains

What observations remain to be made on the other rocks associated with gneiss and mica slate will be found in the following section.

#### *Districts of the Gneiss and Mica Schist System.*

The extent of Countries occupied by gneiss and mica schist with their associated rocks is enormous; and there are few districts of sufficient area where granite appears, without being followed by these deposits. But the order of their succession, and their relative thickness, are very uncertain. In some districts gneiss, in others mica slate, in others quartz rock, make up the whole visible system, and are immediately succeeded by clay slates. There are even cases where the whole system is wanting, and large areas of granite are immediately invested by clay slates and limestones containing organic remains. In England, for example, gneiss and mica schist, and primary limestone, and quartz rocks, are almost unknown; but in Ireland, and especially in Scotland, they are abundant, and include among them many gradations, chlorite slate, talc slate, hornblende slate, &c.

In Eng  
land, &c.

In Cornwall and Wales the granitic rocks are almost universally succeeded by modifications of clay slate; and though in Cumberland the granite of the river Caldew is indeed covered by rocks, having the character of gneiss, mica schist, and dark hornblende slate, (provincially called whintin,) their area is inconsiderable, and the latter rock soon changes to clay slate. At a place called Martindale, at the Eastern foot of Caldbeck Fells, is a fine-grained variety of gneiss in very thin, straight laminae.

Granite veins are rarely known to divide any of the

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rocks of this region. Quartz rock occurs in the Lickey Hill near Bromsgrove, and gneiss and quartz rock were found by Mr. Horner bordering the granite of the Malvern Hills.

The general order of succession among the primary strata in Scotland may be represented in a diagram as in pl. i. fig. 12, but it must be remembered that all the terms of the series are seldom coexistent in the same vicinity.

**Gneiss in Scotland.**

Gneiss is abundant in Scotland, particularly in the Northern and Western parts, and being exceedingly variable in composition, is very often undistinguishable from mica schist, under which head apparently M. Boué has preferred to class many of its varieties.

Gneiss constitutes almost the whole mass of Iona, Tiree, Coll, Rona, and the Hebrides, and enters largely into the composition of the Zetland Isles, which are in some measure to be viewed as a prolongation of the Hebridian group, as the Orkneys appear to be an extension of the Eastern rocks of Caithness. Housa, Burra, Whalsay, Out Skerries, and Yell, and the Western parts of Fetlar and Unst, and part of the Mainland of Zetland, are gneiss. The remainder of the Mainland is principally mica slate, and the two rocks are partially separated from each other by an interrupted deposit of limestone. The gneiss is often porphyritic, as in Unst; at Hagarasattervoe (Hibbert, *Edin. Phil. Jour.* vol. ii.) it appears to contain masses of granite as well as to be traversed by veins of sienite and talcose granite. Kaolin is derived from it in the Mainland and in Fetlar. Gneiss exists likewise in the Orkneys around the granite of Stromness. (Boué.)

In the Hebrides this rock changes often from the typical mixture of quartz, felspar, and mica, by the substitution of talcose minerals and hornblende for mica, by the omission of the quartz, and by the interlamination of argillaceous schist. Some varieties are extremely slaty, and suffer rapid decomposition; others approach nearer to granite, and present rude and naked surfaces and precipitous faces, with few brooks and little alluvium. The direction of the strata in the Hebrides is North-East and South-West, but the declination is obscured by frequent contortions, which in Macculloch's opinion are most frequent in the vicinity of the granitic veins which divide all the gneiss rocks, except those which are associated with clay slate; and the drawing which he presents of the contorted laminae of gneiss and hornblende slate, in connection with ramifying granite veins, near Cape Wrath, seems to justify his views. The laminae of gneiss are often peculiarly bent, or apparently dislocated along the line of the veins; and sometimes masses of this rock are curiously enveloped in their substance.

The veins are not often filled with granite of the ordinary kind, but with a compound rock, in which felspar highly predominates, so as to form in several places (Harris, South Uist, Rona, and Coll) a real graphic granite, which in Coll contains garnets. Veins of quartz, occasionally metalliferous, likewise traverse the gneiss of Coll and Tiree. Garnet, rose quartz, zircon, hornblende, epidote, fluor spar, iron pyrites, and sulphuret of molybdena, occur in the gneiss.

Mica schist is not abundant in the Hebrides, but in Rona, Coll, and Tiree, it alternates universally with the gneiss.

Gneiss occurs in many places, as round the granitic mountains of Bræmar and Lachin y gair, at Kiuncardine

in Ross-shire, and other points in the extreme North of Scotland; but the most abundant and interesting deposit adjoins to the granite of strontian.

It forms the beautiful and picturesque region around Loch Sunart, which strongly resembles the Trossachs of Loch Katrine, being equally rich in wood, and remarkable for intricate confusion of rugged surface.

The curvatures to which its laminae are here subject are very numerous and extraordinary, veins of quartz, felspar, and granite are extremely common, garnets abound in it at certain points, and the metalliferous veins with carbonate of strontian, harmotome and remarkable calcareous spar are highly interesting. On the Eastern side it is bounded by porphyritic masses, but in other directions appears to be overlaid by mica schist, to which its composition approximates.

But the principal part of the Highlands is occupied by the mica schist formation, whose strata, ranging with more or less regularity North-East and South-West, notwithstanding the interruption to their continuity by the unstratified rocks of the Bræmar mountains, and the groups of Ben Cruachan and Ben Nevis.

The South-Eastern limit of this vast deposit is the line of the foot of the Graupians from the Forth of Clyde to Stonehaven. Deposits of red sandstone, lias and a carboniferous part of the oolites border the Eastern coast from the River Spey to Duncansby head, and extend through the Orkneys; rocks of igneous origin, associated with the preceding, mostly occupy St. Kilda, Skye, Rum, Eigg, Mull, parts of Ardnamurchan and Morvern. Within these limits, and with the exception of irregular masses of igneous rocks and of gneiss, the whole of the vast space belongs to the mica slate system, with its included quartz rocks, limestones, serpentines, potstones, its associated hornblende and talcose slates, and its overlying clay slates.

The mountains of this system of rocks are formed into little groups separated by deep valleys and long lakes, and their bases being usually and thickly covered with birch, underwood, and sometimes with forests of oak, while their summits rise often more than 3000 feet above the lakes, the beauty of the scenery is admirable. Scenes, indeed, of an alpine character are very rare in Scotland, and, perhaps, nowhere occur except in the Cuichullin mountains of Skye and the granite peaks of Arran; but very grand and imposing effects are produced by the combination of narrow woody defiles, precipitous slopes, and rocky crested summits. The general outline of the mountains is pyramidal, but this form, elegant at a distance, is broken on a near survey by fantastic projections, and bare cliffs, and by numerous channels, which after storms are changed into a multitude of waterfalls. The valleys destitute of lakes are usually wild and barren, and covered with scattered rocks.

Several of the most remarkable valleys in the Highlands follow the ranges of the strata, as for example, the extraordinary valley of lakes which are united by the Caledonian Canal whose highest summit is but 90 feet above the sea, the valley of the Spey, Glen Tilt, Loch Tay, Loch Long, Loch Fyne, Loch Awe. M. Boué observes, that the longitudinal valleys are remarkably narrow as if mere slits in the country, while the numerous transverse valleys are in general more widely expanded.

One of the most interesting valleys in Scotland is Glen Roy, rendered classical by Macculloch's description

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**Mica schist in Scotland.**

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In the *Geological Transactions*. Two narrow, parallel, contiguous terraces, perfectly level and continuous along the whole length of the glen, mark the higher part of its bordering slopes with a singular and most surprising character, the effect of ancient local operations of level water; most probably an included lake, whose lofty barrier at first subsided a little, and then gave way altogether. It has been with less probability conjectured that these lines are the traces of the ancient margin of the sea, left uninjured during a subsequent elevation of the whole country to the extent, perhaps, of 1000 feet. By the natives of these wild regions they have been traditionally supposed to be the works of man in the fabulous Ages.

As might be expected, the forms of the mountains, and especially the shape of their summits, is considerably characteristic of the kind of rock which constitutes them. Compare, for instance, the irregular head and broken slopes of the Cöbler and other mountains of mica slate, with the smoother sides and less angulated chloritic top of Ben Lomond, and the conical summits of quartz on Benan, Scheshallion, and the Paps of Jura.

Neither are the features of the valleys and waterfalls independent of the nature of the rocks which they traverse. The unequal hardness of mica slate, in particular, is often evident in the rapid streams, by singular hollows and pits in their course, and deep cavities under the cascades. A waterfall near Loch Earn Head exhibits this feature very remarkably.

The most important point of view under which mica slate can be considered mineralogically, is the well-known variation and entire change of character to which it is subjected by alteration in the proportions and permutation in the nature of its ingredients. It cannot be thought surprising that a rock, constituted probably of the debris of many granitic aggregates, should be extremely various in its composition. M. Boué is of opinion, that we may observe on a great scale these variations to be dependent on the general principle, that in proportion to its antiquity or proximity to granite, mica schist becomes more felspathic and more quartzose, in fact, more like gneiss; and on the contrary, that in proportion as it recedes from the fundamental rocks, it becomes more talcose, more chloritic, more argillaceous, in fact, more like clay slate.

Examples of gneiss-like mica slate are found in Glen Tilt, Dalnacardoch, and many other points of the Blair Athol Country, near Tyndrum, and sparingly around the granite mountains of Arran.

In some specimens (Glen Roy) it appears composed of little else than mica folded and twisted round garnet crystals, in other cases (Ben Nevis) the garnets form almost distinct layers. In some cases (Glen Roy) the white mica and quartz form very smooth and attenuated laminae, in others (Frosachs, Loch Earn) the quartz is in thick irregular plates, which mark one of the gradations to quartz rock.

Quartz rocks and quartzose mica slates are seen, in the North of Scotland, in Moidart, along Loch Shiel and Loch Eil, and the Eastern side of Loch Linnhe. Above the granite of Glen Tilt, quartz rocks abound in Ben y glö, and several mountains round the granite of Braemar, and may be well studied in the valley of the Bruar near Blair. They reappear in Mount Alexander and on the sides of Loch Rannoch, constitute the pyramidal summit of Scheshallion, and on the borders of the granitic desert of Rannoch Heath are traversed by

granitic and porphyritic veins. Further West the Island of Jura is distinguished by the obtusely conical quartzose mountains called the Paps of Jura, and the same rocks extend into Isla. Dr. Hibbert has described the quartz rocks in Zetland.

Talcose and chloritic slates, holding an intermediate mineralogical character between clay slates and mica schists, also for the most part occupy the intermediate geological position. They may be well studied on the banks of Loch Lomond and Loch Fyne, and several points on the South slope of the Grampians, where they are often rich in quartz, and remarkable for minute undulations and greater contortions. Chlorite slate is also found in the Long Island, and in Fetlar and Unst. The mica schist of the Highlands very generally contains garnets, which are of various size and occur under different circumstances. It seems difficult to explain the very common association of garnets with mica schist and gneiss, except by admitting that this mineral is one of the effects of heat applied to those rocks since their deposition.

Hornblende rocks, especially hornblende slate, occur in various combinations with mica slate. Hornblende is seen plentifully in Glen Tilt, and is much traversed by granite veins, on both sides of the Pass of Killcrankie, South of Scheshallion, North of Ben More, in the upper part of Loch Lomond, and under Ben Cruachan.

Serpentine, a rock whose geological relations are very imperfectly understood, occurs in Scotland at many places; accompanied generally with talc or steatite, and diallage rock. It is said by Boué to be most frequently placed among the upper beds of talcose slate, though occurrences of serpentine, in small quantities, accompany the limestones of Iona, Glen Tilt, Harris, and Tiree. (Macculloch.) On the South side of the Grampians it occurs only at Cortachne on the North Esk, but through the North of Scotland its localities are more scattered (Near Drimadroit, near Inverness.) The serpentine of Portsoy, said to be employed in some of the apartments at Versailles, forms "three vertical beds," one of them enclosed between hornblende rocks, another between hornblende rocks and primary limestone, and the third between quartzose talc slate and mica slate, which is covered by beds of limestone, hornblende slate, and talc slate, and the junction of all these rocks is softened by a mutual exchange of ingredients. In Scalpa, an irregular, highly inclined bed, one hundred yards thick, of serpentine traverses the gneiss promontory of the lighthouse, and exhibits at its boundaries against the gneiss abundance of hornblende crystals, layers of talc slate, and a sublaminate structure. It contains steatite, asbestos, &c. The granite veins here observed traverse both the gneiss and its included serpentine, and in the latter rock talc is superadded to the ingredients of the vein.

Serpentine exists also in Lewis, and occurs in Zetland in considerable abundance and beauty, both in the Mainland, in Fetlar, and at Brassa Sound in Unst, where it contains chromate of iron in sufficient abundance to be of considerable value in commerce.

Potstone is found in Glen Elg opposite to Skye, and in the serpentine of Scalpa. But the most remarkable rock of this kind is found at St. Catharine's near Inverary, on the opposite side of Loch Fyne. It is imperfectly slaty, and has been employed in the erection of the mansion of the Duke of Argyle. Boué also adds as localities, the districts of Strathern and Breadalbane.

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Talcose  
slates in  
Scotland.

Hornblende  
slate in  
Scotland.

Serpentine  
in Scotland.

Quartz  
rock in  
Scotland.



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Ch II.  
Primary  
limestone  
in Scotland.

**Primary limestone.** One of the most important of the subordinate or interrupted rocks which diversify the vast surfaces of gneiss and mica slate in Scotland remains to be noticed. So much has been before said on the composition of this rock, that we shall here dwell chiefly on the question of the relative ages of the different deposits. In the absence of organic remains, we can only examine the associated rocks, and the texture of the limestone itself. The white marbles of Iona are found in a system of rocks by some referred to mica slate, but considered by Macculloch to be gneiss. The variously coloured marble of Tiree with its imbedded augite and hornblende lies in a system of alternating gneiss and mica slate. That of Glen Tilt, characterised by its accompanying tremolites, lies in a quartzose mica slate, associated with hornblende slate. Notwithstanding the want of agreement in character between the limestones, and the more important differences between the rocks which enclose them, some geologists think these limestones are of the same age.

Bouc, following up the notices of Macculloch, traces the line of the Glen Tilt limestones to the East and to the West. In the Western direction they proceed from Gow's bridge, crossing the hills at Lude, tending toward the South passes through the Glen of Fincastle and across the valley of the Tummel. It is conjectured that limestones of the same range continue by Mount Alexander, and the base of Schichallion, from whence it proceeds through Glen Lyon to the side of Loch Tay, at the foot of Ben Lawers reappears in Crinan Larch, at the entry of South Ffian to the West of East Turbet, in Knapdale, and the head of the valley of Croi.

Toward from Glen Tilt, this limestone is traced in the course of the North Esk, and in the valley of the Dechen Braemar &c.

So extensive a range of limestone rocks in the direction of the strata of mica slate, seems, indeed, to require no additional evidence of its being throughout a contemporaneous deposit. The limestones on Loch Laggan and Loch Lill in Inverness, and at numerous other points in Aberdeenshire are referred by Bouc to the same era.

A second range of limestones, lying chiefly in argillaceous and chloritic varieties of mica slate is considered by the same author to be of more recent origin. The points are near Blurgownie, at the foot of Ben Vorlich on the North side of Loch Linn Balguldher, Inverary, Knapdale, and Torn and the limestones of Balahulish, Canallow, and Dalnally, as well as those which run from Boharm to Bamff, are classed with these more recent limestones.

Perhaps the relations between all these points may not have been correctly ascertained. In every attempt to trace a *contemporaneous line* through the older strata devoid of organic remains, much must be trusted to vague analogies, but there seems excellent reason for admitting that these calcareous rocks, like those which are more perfectly traced among the newer strata, were the produce of a few definite periods, and not mere irregular formations having no relation to each other in respect of time.

The granite of the Isle of Man is followed by very little gneiss, mica slate, and quartz rock. The mica slate is traversed by veins of quartz and schorl. (Henslow, *Geol. Trans.*)

The older strata of the North of Ireland may be considered as in part a prolongation of those of Scotland;

thus the extensive formation of mica slate in Londonderry and Donegal is on the line of the chain of the Grampians, continued through Jura and Isla; and the clay slate ridges which border the Mourne mountains, run in the direction of the Mull of Galloway and the clay slate chain of the South of Scotland, while between these two systems of slates are carboniferous limestone, red sandstone, and other strata of newer origin, corresponding to those which separate the analogous chains in Scotland.

The mica slate rocks are principally of the talcose varieties without garnets, but producing hornblende. Deposits of laminated primary limestone of different colours, containing talc, quartz, hornblende, or pyrites, with veins of quartz, chlorite, and calcareous spar, occur in the mica slate, in many parts of Antrim and Londonderry. Hornblende slate likewise forms distinct beds in the mica slate of this region, and felspar porphyry is described under the same circumstances (Berger, *Geol. Trans.*)

In the South-Eastern part of Ireland, granite is extensively seen, and mica slate forms two ranges along its Eastern and Western boundary, and wherever it occurs is in direct contact with the granite. On the Eastern side of the granite it runs in a narrow course North-East and South-West, dipping steeply South-East, and consists of alternate layers of mica and quartz of extremely variable thickness. On the Eastern brow of Rochtown Hill mica slate runs into a natural hollow of the granite, still retaining the North-East and South-West direction of its strata. On Maulin Hill it is singularly and fantastically contorted on the small scale. There is a prolongation of the body of mica slate at the head of Glenmacanass, gradually narrowed in its Western progress, and constituting a wedge-like mass, inserted into the body of the granite, and enclosing a seeming bed of granite six to ten yards in width, besides irregular masses of granite incorporated with the slate. In the same vicinity greenish, scaly, talc slate lies imbedded in the mica slate, and is used for various purposes of architecture and sculpture.

In Glenmalur occurs a remarkable instance of decided alternation of granite and mica slate under circumstances very favourable for its display. In a space of 204 fathoms no less than five distinct alternations of granitic beds with as many layers of mica slate, are clearly traced, and several of these beds are compound, or really made up of similar alternations of granite and mica slate, or quartz and mica slate. The great mass of granite is below, and the great mass of mica slate above constituting the hill called Lugduff. Grenatite abounds in this slate.

Similar alternations occur in other neighbouring places making a total thickness of one-third of a mile and the whole system ranges North-East and South-West and dips South-East. On the North-East they probably abut, and terminate against the granite. The mica slate on the summit of Lugnaquilla is likewise interstratified with granite. Clay slate bounds it on the East, and at length coming into contact with the granite cuts off its further progress to the South.

On the Western side of the granite the mica slate is still less extensive. It is found to enclose beds and elliptical masses of granite in Glenismaile, and it is mentioned that a granite vein, four to eight inches wide, ranging 25° North of West, cuts off the mass of alternating strata, without occasioning any displacement. In

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See and  
sculpture of  
granite  
in stone.

North of  
Ireland.



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the same valley are two distinct beds of compact greenstone porphyry in the mica slate, one four feet wide, the other two feet. Andalusite abounds in the mica slate of this country, and greenstones of various kinds alternate with it.

The frequency of the phenomenon of alternation between mica slate and granite is a singular feature in the Geology of this part of Ireland, for the full display of which we are indebted to Mr. Weaver. (*Geol. Trans.* vol. v.)

In Brit-  
tany.

The tract of old rocks in the North-Western part of France is one of the most extensive in Europe. The granite, generally the most elevated, is separated from the secondary strata by a system of gneiss and mica slate, and by another system, into which they pass almost indefinitely, of clay slates. In the Departments of Calvados and La Manche these two systems appear as zones around the granite, the gneiss being within the clay slate. Quartz rocks of blue colour, and pegmatites with tourmaline, are associated with them, and veins of quartz and granite traverse them. (De Caumont, *Geol. du Calvados*.)

In the Py-  
renees.

The granitic masses of the narrow chain of the Pyrenees having been uplifted in much confusion, are very irregularly bordered, in several places they are overlaid by gneiss and mica slate, but generally by the clay slate series. Charpentier, a disciple of Werner, thinks the gneiss of the mountains which border the valley of Soulan, so intimately connected by gradation and alternation with the subjacent granite, as to be necessarily united therewith into one formation. In many instances gneiss and granite are described as alternating in very thin layers. In other cases, vast blocks of micaceous gneiss of 100 cubic fathoms' bulk are buried at intervals in granite, always preserving one constant relative position or direction of strata. These are thought by Charpentier to be of contemporaneous origin with the granite, which passes into them at the sides, and thus interlaminates the gneiss.

Mica slate, in the same manner, is intercalated with granite in a great many places, and quartz and felspar bands occur in the granite. In many places in the Pyrenees the "granite" contains beds of stratified granular limestone, (such as in other districts lies in the gneiss,) with graphite, talc, fluor spar, mica, hornblende, &c.

The more modern view of these phenomena is that they are quite consistent with the doctrine that granite is an igneous, but gneiss and mica slate originally aqueous rocks, and that in some cases what is called granite, is in fact gneiss with the aspect of granite, derived from a more than usual condensation and greater effect of heat. M. Boué, Dufrenoy, and other writers, have proved beyond a doubt the powerful action of heat along the Pyrenean chain, as evinced not only by the usual subcrystalline character of the clay slates, but also by the metamorphism of the chalk into the characters of primary limestone, with abundance of metallic and granitic veins at the line of junction of the altered stratified and the igneous rock. The age of the eruption of granite along this chain is, by observations of Dufrenoy, determined to be, at least in part, posterior to the chalk.

It is extremely probable that the same kind of explanation will be found to apply equally to the alternation of granite and slates in Ireland and Cornwall, and to the alternations of porphyry and slate in Cornwall

North Wales, and Cumbria. It is to be remembered, however, that the igneous theory, as it has been termed, does not by any means require that all these beds of seeming granite should be pronounced to be altered gneiss, nor that the beds of porphyry should be considered as altered clay slate. Alternating igneous and aqueous action is perfectly intelligible, and exemplified in modern operations of Nature; but certainly in many cases, both in Cornwall and Cumbria, it appears the more correct view to suppose a gradual and partial *rearrangement* of the materials of the rock, through the long action of heat. This would well agree with the indefinite boundaries of the porphyries of Cornwall and Cumbria, which often pass by insensible modifications into ordinary slate.

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The great central plateau of old rocks in France from which the Loire, Vienne, Dordogne, &c. take their source, is chiefly a granitic and porphyritic tract, surrounded by oolitic and carboniferous rocks, but clay slates and gneiss rocks appear in the valley of the Vienne, and occupies a large part of the Southern boundary. Near Limoges are alternating beds of granite and gneiss, and some subordinate beds of pegmatite and hornblende rock: the gneiss passes by one variation to granite, by another to mica slate. The ranges of the strata near Limoges are North-East and South-West, and they are crossed by decomposing elvan courses to North North-East. Tin veins occur near Vaulry in gneiss as well as in granite. Towards the borders of the district the gneiss becomes less granitic, more associated with hornblende slate, and encloses deposits of micaceous limestone. Serpentine lies in this gneiss in many places, and M. Cordier appears disposed to refer them all to one contemporaneous, though interrupted deposit. The pegmatites and kaolins, which have resulted from them by decomposition, of St. Yrieux, form numerous veins and strings in the gneiss and hornblende slates, which sometimes intercalate themselves between the laminae. Quartz rock of bluish colour exists likewise in the Black Mountain and elsewhere. Oxidulated iron abounds at many points in the gneiss; galena, phosphate of lead, carbonate of copper, antimony, and hematite, are the products of the veins. (Desnoyers.)

In central  
France.

The most remarkable alterations of secondary limestones take place, according to Dufrenoy, along the line of junction with the granitic and porphyritic masses. Thus the limestone becomes metamorphic, and are traversed by metalliferous veins, as in Cornwall and Brittany, where the slates are metalliferous principally in the same situation.

After these details of the circumstances attendant on gneiss and mica slate at so many interesting points, we shall only add some general observations on the range and extent of this system of rocks in other Countries. Gneiss and mica slate in small quantity occur in the Vosges, and gneiss more abundantly in the Black Forest.

Other lo-  
calities in  
Europe.

The long irregular chain of the Alps contains a vast quantity of gneiss and mica slate, variously extended around the talcose granite cores of Mont Blanc and St. Gothard, from the Mediterranean almost to the Danube.

Deeply buried beneath the valley of the Danube, gneiss and mica slate do not reappear around the granitic origin of the Carpathians. Their place is supplied in this chain by a vast deposit of clay slate.

The primary mountains which encircle Bohemia are

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on all the Southern half granite. Gneiss and mica slate are superadded on the West, and the former rock in particular abounds in the Erzgebirge. The Riesengebirge granite is bordered on the North by gneiss, on the South and East by mica slate, and these rocks are associated with granite in the range which divides the drainage of the Oder and the Elbe.

These rocks are most extensively spread over the Northern parts of Europe, from Copenhagen round the Gulf of Bothnia, along the Uralian chain toward the Caspian Sea and the Caucasus.

In Amer  
ica

In America, Humboldt describes gneiss as less abundant along the high chains of the Andes than along the inferior mountains of Caracas in Orinoko, Brazil, New Spain. It is occasionally auriferous and contains micaceous, primary limestone. The most considerable masses of mica slate mentioned by this distinguished traveller are those of the Cordillera of the shore of Venezuela. This formation in the Andes is less rare in the North than in the South of the Equator. No where perhaps is the total suppression of mica slate formations more frequent than in the Cordilleras of Mexico and South America.

The Eastern primary range of North America passes through the United States from St. Lawrence to the Mississippi in a direction nearly parallel to the coast, and generally 100 miles distant from it.

Gneiss is the most extensive of the primary strata in the Northern States of America, filling large tracts in New Hampshire, Massachusetts, Connecticut, the Highlands of New York, Pennsylvania, Virginia, &c. and the Southern Counties. It retains in general its place next to the granite and is often succeeded by hornblende rock. It contains deposits of primary limestone, calcareous sandstone, and in several places laminated plumbago adulteration, magnetic iron ore.

It is traversed by veins of granite in Madagascar full of beryl, sapphire and other minerals.

Mica slate is less extensively prevalent and occupies a narrower course in Massachusetts, Connecticut, the Highlands.

Talcose slates succeed and granitic breccia appear in ranges above it in Connecticut, Pennsylvania, and Maryland. It is often micaceous or dolomitic in Massachusetts and Connecticut.

Quartz rock occurs in the Western part of Massachusetts.

### Slate System.

Inversely  
proportional  
to the  
gneiss and  
mica schist

It may be taken as a general rule that the two systems of rocks which compose the primary strata are inversely proportional to each other. Countries which abound with gneiss and mica schist are indeed seldom quite devoid of clay slate, but they also seldom contain it in great quantity. On the contrary, where clay slate is extremely abundant, gneiss and mica slate are less extensively developed. This is at least very much the case in the primary mountains which surround and diversify the basin of Europe.

In Scotland the Grampian ranges, and, in fact, all the Northern primary strata of that Kingdom, are principally composed of mica schist and gneiss, while clay slates prevail almost exclusively in the Southern chain of the Lammermuir and Galloway ranges. As before observed, the mica slate system in Ireland is distinct from the clay slate tract. The Cumbrian granitic rocks are surrounded by clay slates in great plenty and variety,

but there is little gneiss or mica slate. The same is observed in the large primary tracts of Wales, Devon, and Cornwall, and it is a characteristic feature in the Geology of the Harz.

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For the purpose of clearly unfolding the relations of the various argillaceous, calcareous, and conglomerate rocks which compose the vast and variable mass of the clay slate system, it is desirable to fix our attention upon some district where the variety of the rocks is considerable, and the order of succession is perfectly known. Such is the district which overlooks the Northern English lakes. We shall, therefore, describe it as a type of the clay slate system, and refer to it as a constant term of comparison.

The granite of Skiddaw is covered by gneiss and hornblende slates. The latter rock gradually changes to the chlorite slate and other argillaceous slate of Skiddaw. The argillaceous slates here commencing form a series of three members, distinguished by their mineralogical characters and a constant order of succession. See pl. fig. 13.

The lowest late rocks of the system range to the South West from Skiddaw and Saddleback by Girdale Pike to Dent Hill filling the valleys of Derwentwater and Crummock water. South West of Buttermere, they are concealed by the elevated ranges of High Street and Red Pike but reappear in the lower parts of Finnerdale, and abut against the limestone border near Egremont.

The slate of this district is generally of a dark bluish colour, and of very uniform texture, soft, fine grained, and very fissile and has been employed in the vicinity of Keswick and Hesketh Newmarket for roofing houses, but for this use it is not very suitable, for it easily perishes in the atmosphere. In consequence of its want of durability the mountains of this slate have smoother contours, more uniform slopes, and a more verdant surface than those of the following series.

In one point on the South Western edge of Derwentwater we have observed an undulated variety of this slate of piler colour and more shining surfaces, indicating an approach to the nature of chlorite slate. Chlorite is imbedded in the lower part of the rock in Skiddaw and Bowscale Fell. Where this slate shows itself by the sides of the lakes its laminae appear to be generally vertical and often flexuous. Veins of quartz are frequently seen penetrating and interlaminating its masses. In several places they yield abundance of lead ore, and in the district called Newlands, abundance of carbonate of copper, and some cobalt. Mr. Otley states that the lead veins run North and South, and those of copper East and West. Stannite is found in Borrowdale, and mixed with the slate in Martindale. Two salt springs have been detected in it near the upper end of Derwentwater.

These rocks sloping to the South East and North West from Skiddaw and Saddleback, are covered by the middle system of slates. These are best developed on the South Eastern slopes, and occupy a long range of mountains parallel to the Skiddaw slates, in those highly picturesque and romantic valleys wherein the lakes of Ulswater, Havereswater, Thirlmere, and Wastwater, spread their beautiful waters.

The lowest rock belonging to this system is a red, argillaceous, fissile stratum, abundant in the Eastern shores of Derwentwater, especially about Barrow and in St. John's Vale, in both localities resting upon the Skiddaw slate.

Gneiss and  
mica slates

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Red rock.

It is a very singular rock, characterised universally by its mottled colours, and apparently heterogeneous composition. Its first aspect reminds us of an old red sandstone conglomerate, but on closer inspection the seeming certainty of its brecciated character vanishes; the seeming fragments of which it is composed appear to be scarcely more than colour spots, and we leave the rock very undecided as to its origin. In some cases, however, it must be owned, the appearances of aggregation are very difficult to withstand. It is distinctly stratified, with dip to the South-East, and is of considerable thickness. Its pervading tints vary from bright red to purple, and in proceeding up Borrowdale, rocks succeed in the same geological position, at first blue, and afterwards greenish, while the seeming conglomerate aspect becomes less distinct, the spotting is smaller, the hardness greater, the rock splits vertically, and becomes, in fact, a coarse green slate. Amidst the numerous varieties which succeed, we perceive about the Bowder stone some remarkable laminated beds, with talcose surfaces, and variegated with nodular concretions of calcareous spar, green earth, and differently coloured quartz or calcedony, having altogether very much the aspect of amygdaloid. This peculiar slate, which seems to indicate the united agency of water and great heat, dips in the same direction as the red rock of Barrow, and thus helps to prove that in this tract the vertical cleavage of slate is transverse to the lines of deposition. It appears to harden and change character in Wallow Crag. There are, perhaps, repetitions of this remarkable rock in other parts of the slate systems, since it occurs at the upper end of Ulswater, in Helm Crag, Loughbrigg, and other points about Grasmere and Elter Water, in Ulpha, and other places. But it is possible that these may be the same beds; a conjecture supported by the fact, that red rocks, like those of Barrow, lie beneath them at Grasmere. And, indeed, in Helvellyn and other mountains we see the coarse slate rock vary through all appearances from amygdaloidal slate to fragmentary greywacke, and thus again assuming more regularity, resemble clay porphyry, from which its uncrystalline felspar and recurring fragmentary structure do not always clearly distinguish it. On the other hand, we see the coarse rocks of Borrowdale and Patterdale lose their spotted aspect, become more uniformly green, more regularly fissile, and change to the fine-grained green slates of Langdale and Conistone Fells, or the pale grey rocks around Grasmere, or the "rain spot" slate of White Moss.

Greenstone rocks are variously associated with this system of slates, sometimes in the state of dykes, sometimes as overlying masses, particularly about Keswick. The sienitic rock of Red Pike, Scaleforce, and Wastdale, which seems to come up through the lower slate, ramifies its masses through and over these rocks. Red porphyry dykes divide them on Armbath Fell; large masses of red and dark porphyry with garnets, lie on their lower portions in St. John's Vale; and if the slate of High Pike belongs to this system, the felspathic (or elvan?) courses there known, may be added to more massive accumulations of igneous products which border Thirlmere Lake. The sienites and hypersthènes of Carrock Fell, and the granitic tracts of Wastdale and Devoek Lake, must probably be viewed as rising upwards from below the whole series, and spreading on the surface of the strata of slate.

The minerals which this district yields are rather

numerous than valuable. The veins are generally quartzose. A great variety of lead spars, sulphuret and carbonate of copper, with galena, pitchy iron ore, wolfram, &c. are found in Caldbeck Fells, among the slaty and sienitic rocks. Galena has been worked in Gristdale, (Ulswater,) copper ores at Conistone and in the lower beds in Newlands, plumbago in Borrowdale, micaceous iron ore in Eskdale, &c.

In consequence of its superior hardness, and its frequent association with igneous products, the green slate mountains assume bolder forms, present more lofty and rugged peaks, and more inaccessible precipices than the softer slates of Skiddaw. For the same reason, the streams instead of furrowing the smooth slopes in straight courses are twisted about among the unyielding rocks, and broken into admirable cascades.

The region of green slate is rather indefinite toward the South-East, where it is overlaid by the uppermost series of greywacke slates. Perhaps it may be best to adopt as the conterminous line, the narrow course of dark calcareous slate ("transition limestone") which passes from Long Sleddale by Low Wood Inn and Windermere Head to Conistone Water Head and Broughton Mills. This rock contains organic remains, as caryophyllia, millepora, producta, spirifera, orbicula; but generally in so imperfect a state of conservation that their specific characters are very obscure. The calcareous layers alternate with layers of slate of the same colour, and are with difficulty distinguished from them. Their dip is usually very rapid.

Above this regular band of limestone lies a thick series of rocks, containing several varieties, all capable of being ranked as greywacke. The lower rocks, very dark in colour, are frequently quarried for slate, (Broughton, Ulverstone, &c.) occasionally for flagstones and tombstones, (near Hawkestone, crooks of Lune, &c.) which are sometimes parallel to the stratification. (Otley, *Guide to the Lakes*.) In the long aberrant range of slate rocks beneath Ingleborough and Penygant, (*Geol. Trans.*) dark slate of similar aspect reappears in Clapham Dale and between Ribblesdale, and furnishes enormous tables of slate with nodules sometimes formed round lituities, in the nearly vertical partings or cleavage. At Ingleton the greenish slate seems rather referable to the middle slate system.

Above the dark uniform slates previously described lies a system of more micaceous and more granular rocks, which extend to the South-Eastern border of the primary district. They are of two kinds: 1. fissile with micaceous partings parallel to the stratification, sometimes reddish, and appearing to resemble certain laminated red sandstones. 2. Granular, not fissile, with disseminated mica. These varieties may be observed frequently alternating in the country North of Kendal and about Kirby Lonsdale, and present the most striking analogies to arenaceous freestone and micaceous flagstone. In the upper part of this system (near Kendal and near Kirby Lonsdale) lie layers of shells, or rather casts and impressions of shells of the following genera: orthoceras, patella, trigonia, plagiostoma, pecten, gryphaea, turritella, melania, spirifera, terebratula. (*Geol. Trans.*)

A very remarkable feature in the region of this upper slate series, is derived from the uncommonly crystalline aspect of the rock on a large scale. The numerous joints intersecting one another at acute angles, and ranging with admirable precision for a hundred yards or

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Dark limestone.

Upper slates.

Cleavage of slate.

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more, divide the faces of the hills into long ridges of smooth, rhomboidal rocks, alternating with parallel heathy or grassy hollows. This is probably the reason of the peculiarly rough and knotted appearance of many hills of this tract. It is difficult to resist the belief that this is owing to a real crystallization, and that slate is a crystalline rock with definite angles and regular cleavage. But on pursuing the inquiry it will be found that the parallelism of external joints and internal cleavage is a phenomenon of a different kind from geometrical crystallization, not produced in consequence of an original equilibrium amongst the particles, but from symmetrical consolidation of the mass, exactly as the cuboidal blocks of oolite, the rhombs of shale, and prisms of basalt have been formed.

Among the common appearances of cleavage is that represented in pl. i. fig. xiv. where different layers (strata) of slate are cleavable at different angles of incidence.

Scotland.

It will be difficult to put the slates of Scotland in comparison with those of Cumberland, as they are deficient in limestone. In general terms it may be said, that the dark pyritous slates of Argyleshire and the West of Scotland seem analogous to those of the lower Cumberland group; but those which constitute the Lammermuir and Dumfriesshire mountains have the characters of the greywacke system.

Ireland.

Mr. Weaver describes the slate which borders the granitic tracts South of Dublin, as alternating with greenstone and greenstone porphyry, and enclosing clay slate conglomerates.

In Windmill Hill, Mr. Weaver describes several alternations of a granular felspathic rock with the clay slate. And in the mountain of Croghan Kinsela, in the space of 630 fathoms, are eight principal beds of alternating granite and clay slate, besides several of granite and clay slate mixed, and four of clay slate and greenstone.

Clay slate and quartz rock are likewise seen in frequent alternation on the Eastern coast of Ireland, and thus remind us of the similar rocks in Anglesea. No organic remains have been found in these tracts; but Mr. Weaver describes the occurrence of fossil plants perfectly analogous to those of the carboniferous rocks in coal seams of the South of Ireland, supposed to be included in the greywacke slates.

Isle of Man.

In the Isle of Man, Mr. Henslow is inclined to consider in one instance the cleavage and stratification coincident. Elvan dykes and granite veins divide it.

Wales.

In Wales, according to Professor Sedgwick and others, the slate system between the old red sandstone and the granite presents the following general characters in a descending order.

1. Greywacke containing, in a state of considerable development, several divisions, calcareous, arenaceous, and shaly, with organic remains, in considerable numbers and variety. (Buallt, Llandilo.) The layers of the upper part of this rock conduct us by an easy transition into old red sandstone.

2. The great slate formation, containing in all its parts indications of mechanical origin. Detached deposits of limestone.

3. A vast group, differing from the ordinary character of the Welsh mountains, in containing a very large proportion of felspathose rocks of porphyritic structure. Of this the mountains of Snowdonia are probably the lowest portion; they contain organic remains.

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4. A group of slaty rocks described by Henslow in Anglesea, consisting of chlorite and mica slates, and quartz rock.

Nearly all that is valuable in the Geology of the slate system of Wales is due to Henslow's description of Anglesea, Sedgwick's labours in Snowdonia, and all its intricate dependences, and Murchison's recent and detailed investigation of the South-East portion of the district from Shrewsbury to the mouth of the Towy. The results of this friendly partition of labours have been eminently successful; while in the North-Western district the general inferiority of position of the chloritic and micaceous schists to the whole clay slate system of Wales is clearly proved; the true place of the Snowdonian shells fixed in the very lowest portion of the clay slate; the extent and effects of subterranean convulsion and intrusion of igneous rocks, very fully pointed out: these phenomena have been linked by discoveries on the other side of the region into a complete system of slaty deposits. The greywacke series on the South-East border, described by Mr. Murchison, fortunately presents a series of phenomena, deficient or not clearly separated in the slate district of Cumbria,—a vast number of organic remains, lying in distinct groups, a series of distinct members of the greywacke, which these fossils appear to characterise, limestones of different ages which clear up the difficulty, always felt hitherto in fixing the true relations of the limestones of Dudley and Llandilo; and, finally, ancient Plutonic operations accompanied by elevations and alterations of the strata. We may now, upon sufficient data, affirm that the Welsh and Cumbrian series of slates presents a nearly complete record of all the principal deposits, with their characteristic organic remains from the gneiss and mica schist upwards to the carboniferous system; and, as these slates graduate below into the mica schist system, and above into the old red sandstone, to show a continuity of marine operations in a part of the geological scale of periods where formerly was an utter blank? Mr. Murchison finds the greywacke series divisible into six groups, in the following descending order, all ranging North-East and South-West.

The first group, below the old red sandstone, is a series of thin-bedded arenaceous-calcareous strata, 1000 feet thick, abundant in the neighbourhood of Ludlow, and stored with brachiopodous bivalves of the genera terebratula, strophomena, leptæna, and orthoceras; and trilobites of the genera homonolotus and calymene.

Groups in the upper slates of Wales.

The second group is limestone 100 feet thick, in its upper part interlaminated with the superior beds, and below resting on shale. It is identical with the celebrated limestone of Dudley, contains nearly all its well-known fossils, and ranges in a continuous escarpment for many miles North-East and South-West, but grows thinner continually to the South-West, so that in the prolongation of the strata parallel to the South Wales coal fields this interesting rock is nearly extinct.

The third group is the dye earth of Shropshire, which was once supposed to overlie the Dudley limestone. It is, perhaps, 2000 feet thick, and is made up of incoherent, greyish, argillaceous, sometimes micaceous schist. The higher strata are in some places charged with many orthocerata, lituites, asaphus caudatus, &c. Other beds are locally distinguished by concretions of argillaceous limestone formed around corals and other

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organic bodies; and toward the base of this deposit a thin, calcareous zone is observed in Shropshire, containing the *pentamerus lævis*, Sow. and a new species of that bivalve.

The fourth group is an arenaceous sandstone series of various colours, chiefly red and blue; calcareous bands are associated with the sandy strata, almost made up of *productæ*, *leptæna*, and *spiriferæ*, with crinoidal remains, all of species peculiar to this group. Thickness 1500 or 1800 feet.

The fifth group consists principally of black shale enclosing beds of greywacke, flagstone, or calcareous slate, which, prolonged to the South-West, join themselves to the trilobite beds of black limestone and calcareous flagstone at Llandilo, and thus establish the distinctive relations of that rock to the Dudley limestone. The thickness of this group probably exceeds that of any of those mentioned above.

The sixth group is a vast deposit several thousand feet in thickness, consisting of red, coarse, quartzose conglomerates, schistose beds, and purple-coloured sandstone. No organic remains have been yet observed in this group.

Below all these comes the great slate formation with detached masses of limestone, also ranging North-East and South-West, as about Bala lake.

Charnwood  
Forest.

In Charnwood Forest the sienitic rocks are followed by clay slates of different kinds, compact and coarse, soft and silicious, green or dark coloured.

Cornwall  
and Devon.

In Cornwall and Devon the order is,

1. Greywacke, with calcareous slaty beds sometimes containing organic remains, and detached deposits of limestone.

2. In two places a serpentine formation, which, in the Lizard, contains diallage rock, talc slate, hornblende slate, and mica slate, appear to occur beneath the greywacke. Its relations are obscure, but it is superior in position to the following formation.

3. The great formation of metalliferous slate (killas) with many subordinate beds of greenstone, felspathic slate, &c. It is traversed by granite veins, and is said to alternate with granite.

Dr. Boase, in his recent Work on the *Geology of Cornwall*, arranges the schistose rocks of Cornwall in two groups, the upper of which is associated with black calcareous slates, and the lower much interlaminated and mixed with porphyritic masses, enrites, quartz veins, &c. At its junction with the granite, the killas is frequently intermixed with granite veins, and is altered in some respects so as to lose in part its fissility, and to be described by the miners as "Elvanny Killas."

The general impression concerning the schistose rocks of Cornwall is that their mineral composition is a mixture of quartz, felspar, and mica; and so, probably, is that of most clays and shales.

The extensive deposit of serpentine of the Lizard is seen in several places to rest upon and alternate with greenstone and porphyry, in others to rest upon green talc or clay slate. At Coverack are rocks of various texture, in some measure intermediate between serpentine and diallage rock, which suggest important reflections on the relation of this beautiful rock; and, in the same place, the greenstone abounds with diallage, and contains likewise titaniferous oxide of iron. Veins of steatite divide the serpentine, and are thought by Sir H. Davy to be derived from decomposed felspar. Dykes of

sienite, and saussuritic diallage rock pass through the serpentine.

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The clay slate deposits of Brittany are said to resemble those of Cornwall. Very similar serpentine occurs there, and in addition *ogygia*, *calymene*, *euomphali*, and *posidonias*.

Two-thirds of the area of the chain of the Pyrenees is composed of clay slate, which appears to exhibit varieties of texture and aggregation like those described in the Cumbrian district, with the exception of the coarser kinds being dark green, micaceous, or granular, aluminous or silicious. Frequently these slates alternate in very thin layers with limestone, in which case a number of calcareous fibres crossing the slate, but not the limestone, give the mass the peculiar appearance of schiste rubané; limestone abounds with this slate series, and is either compact, slaty, or granular. It contains crinoidal and zoophytic fossils, "ammonites," and a few other shells, and some are found in the alternating slates. Anthracite in small quantities is mixed with the slates, quartzose, felspathic, and greenstone rocks alternate with them. Most of the metallic products of the Pyrenees are found in the clay slate system. (Charpentier.)

The Ardennes mountains, which cover so vast a tract in France, Luxemburg, and the Rhenish Provinces, and which support the volcanic products of the Eifel volcanos, are mostly composed of greywacke slate analogous to the upper part of the Cumbrian system. Good roofing slate is not common in this tract. Remains of ferns, like those of the coal beds, of *productæ* and *encrinites* occur in it.

Organic remains are not very rare in this formation Rhine on the banks of the Rhine. In the valley of Nieder-labenstein we found the greywacke slate rich in fossils, among which *spiriferæ* were most numerous. The lower part of the slate series of the Rhine appears to be the most quartzose, and it will be found occasionally difficult to say whether a particular rock should be called greywacke, or quartz rock.

The slates of the Harz contain *productæ*, *calymene* Harz, *tristans*, *posidonia becheri*, &c.

The slate system of Scandinavia presents a general analogy with that of Cumbria. In its upper part are black limestones in nodules or beds alternating with slate and containing trilobites of the genera *paradoxites* and *agnostus*, and *orthoceratites*.

The group of the Tarentaise, referred by MM. Brochart and De Buch to the age of transition rocks, is very dissimilar from the general character of the deposits of that period. Consisting of granular and talcose limestones, gneiss, and mica slate, it may be compared to the earlier primary rocks, while the organic remains sometimes found in it, and the coarse greywackes which belong to it, unite it to the latter period of the system. (Humboldt.) Similar remarks are applicable to the metamorphic strata of the Valaisine, and perhaps, in both cases, the peculiarity of aspect is much dependent on the local influence of heat derived from the neighbouring granitic masses and veins.

Clay slate is the lowest rock in North America containing organic remains, which are always of marine origin, and it rests immediately upon granular limestone. These remains are extremely rare: *brachiopodous* bivalves and *orthoceratites* are found at Troy. This rock may be traced over a space of two thousand square miles, in the Counties of Saratoga, Schenectady, Albany,

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**Rensselaer, and Columbia.** It extends into the Western margin of Massachusetts, and there rests immediately on granular limestone. (Eaton.) Its laminae cross the planes of deposition as in the slates of England, and all the accidents to which the European slates are subject are repeated in America. It is silicious about Hudson's. Clay slate is not extensive in South America.

### Transition Limestone.

Analogous  
to older  
primary  
limestones

The limestones associated with clay slates are almost universally known to Geologists by the name of Transition Limestone, a term which we think liable to little objection, even by those who reject the title of Transition Strata, as applied to the whole or any considerable part of the slate system. These limestones are usually, as in Norway and Cumbria, of a very dark colour, fetid when struck, and more or less associated by alternation and gradation of characters with the slate rocks; or they are mere calcareous slate, as in some parts of South Wales; or they form considerable rocks, as in the Eifel, at Dudley, in Shropshire, and Herefordshire. There are also in North Wales and Devonshire portions of limestone more analogous in character to the primary limestone, and like that very limited in extent, appearing like huge ellipsoidal concretions wholly enveloped in slate. These latter, like primary limestone, are generally deficient in organic remains; they appear to range parallel to the original planes of stratification in the slate, and may thus eventually be found of great use in subdividing that thick system of deposits. They may be considered as generally, perhaps universally, more ancient than the more connected range of limestone and calcareous slate with organic remains. It is in the upper part of the slate series in South Wales, Herefordshire, and Cumberland, that the limestones with organic remains are found.

by the manner  
of its  
accumulation.

But even the most connected portion of this upper transition limestone is liable to so great alteration of quality and variation of thickness as to present some points of analogy to the earlier calcareous deposits. From very thin and unimportant traces above the Vale of Towy, the uppermost limestone swells out to a considerable thickness in Herefordshire, Shropshire, and Dudley, and the number of organic remains varies in the same proportion. About Ludlow the thinner beds of this limestone occur principally in nodules united with much shale, both containing orthoceratites, trilobites, &c. Even amongst the thicker beds of the limestone rock, Mr. Murchison has recognised the same remarkable tendency to ellipsoidal concretions.

The transition limestone of the Hartz presents two considerable independent masses, enclosed between conformed strata of greywacke. Near Rüttslau, East of the Brocken, it abounds in madrepores, which, however, are chiefly rendered visible by decomposition of the rock. This character also obtains in much of the dark limestone of Norway and of the Cumbrian lakes. The laminated limestones of South Wales and the Eifel, are of a lighter colour, and generally associated with shales and grey or reddish sandstones, such as usually belong to the top of the slate series. The fossil remains of these situations are in consequence usually well exhibited on the surface of the beds, when, either naturally or by chemical or mechanical means, these surfaces can be cleared. (M. de Bonnard, in *De la Beche's Memoirs*.)

As on the one hand the irregularity and frequently

nodular character of the limestones associated with slate, present a curious analogy to the older calcareous rocks of the gneiss and mica slate system, so the upper fossiliferous limestones of the slate, have often a special resemblance to the mountain limestone of the succeeding epoch, both in mineralogical character and organic remains. Judging from specimens only, and from an imperfect view of the English and Belgian series of strata, many Continental Geologists have been unable to discriminate between our transition and carboniferous limestones. Their conclusions on this point appear to have been sometimes influenced by the fact that trilobites and orthoceratites, as well as many encrinites, occur in both these rocks. Nevertheless they are really and permanently distinct, and their organic remains belong undoubtedly for the most part to very different species, and present altogether perfectly characteristic groups.

No English Geologist can for a moment hesitate to distinguish the fossils of the transition limestone of Malvern and Dudley, on the one hand, from those of Derbyshire and Flintshire on the other, nor should it be found difficult to separate in like manner the transition limestone of the Eifel from the carboniferous limestone of Namur. Both it is true are contiguous to slate, nor do they occur superimposed in one section; but the Namur limestone lies on the greywacke of the Ardennes, that of the Eifel is enclosed in it, and forms really a part of the slate system, as much as the limestone of Christiana, Cumbria, and Caermarthenshire. One principal reason of the confusion among Continental writers on the subject of these calcareous deposits in England, is the almost universal deficiency of the true carboniferous limestone beneath all the coal fields of continental Europe, except those of Mons, Namur, Liege, Dusseldorf, &c.

Finally, we must repeat the remark formerly made, that all the hard lines of distinction, which for convenience we draw across the scale of strata, may be locally exact and defined, but ~~vanish~~ on a more extended comparison of distant localities. The limestones of the slate system, generally, appear to connect the oldest calcareous rocks of the gneiss with the comparatively modern limestones of the coal measures. The greywacke slates which enclose them are also so much changed from the type of clay slate, as to assume very nearly the aspect of sandstones and shales, frequent in the carboniferous system; and thus, both by analogy of fossils and gradation of mineralogical characters, we are led without any startling chasm from the primary to the secondary strata.

Moved by these considerations, some eminent English Geologists appear disposed to unite together the carboniferous system and the transition limestone group, and in some cases this may be a very convenient mode of arrangement; but tried by general comparisons it seems to offer no special advantage. For, by the same rule, we ought certainly to form but one class of rocks from the gneiss to the new red sandstone, since it can be most clearly proved that, in all this vast series, alternations and gradations prevail; but further, we should by rigorous extension of this mode of classification, have no division at all from the gneiss to the tertiary strata. In fact, it is already certain that the whole series of strata is a consequence of repeated actions of the same causes under modified circumstances, and the classification of the strata must be left in a great measure to the moderation and local convenience of the cultivators of Geology.

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to the newer  
carboniferous  
limestone,but distinct  
from both  
in England,  
&c.The whole  
series of  
strata one  
system.

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There is little doubt that the line here drawn between the slate system and the carboniferous system may be easily recognised throughout Europe; and if in some cases the upper slates assume the aspect of sandstones and shales, and even contain traces of coal and plants, such as usually occur above, and the two sets of limestones thus divided resemble one another in certain mineral characters and organic remains, this ought not to surprise us, for it is a part of the general process of Nature.

Succession  
of primary  
strata.

To these remarks we shall only add a short connected view of the sequence of limestones in the whole primary period, according to our notions of their affinity, placing them in a descending order, with their alternating strata.

- In the slate system.
- a. Arenaceous, calcareous, and argillaceous strata containing organic remains.
  1. The limestone of Dudley, Ludlow, Herefordshire, full of organic remains.
  - b. { D. earth of Shropshire, containing organic remains and calcareous concretions.
  2. Arenaceous strata with organic remains and calcareous bands.
  2. Llandilo limestone, associated with black shales, both containing trilobites and other fossils.
  - c. Upper greywacke slates of Westmoreland, containing orbicula, orthocera, and other organic remains.
  3. Black slaty limestone of Westmoreland, with cyathophylla, millepora, orbicula, but hitherto no trilobites. Probably the limestone of Okhampton in Devonshire, and that of Bala in North Wales.
  - d. Slate rocks
  4. Detached limestones of North Devon and North Wales.
  - e. Slate rocks, rarely containing a few shells.
  - f. Chloritic and micaceous schists of the Grampians.
  5. Crystalline limestone of Loch Earn, Inverary, Dalnally, no organic remains.
  - g. { Chloritic and micaceous schists.
  - h. { Mica schists and gneiss.
  6. Crystallized limestone of Glen Tilt, Strathfillan, Glen Croe, no organic remains.
  - h. Gneiss, mica schist, &c.

#### General Conclusions concerning Primary Strata.

The general system of operations disclosed to us by an examination of the primary strata, presents the following leading points.

A general  
basis of  
igneous  
rocks.

1. The lowest rocks which we can trace, those upon which the vast accumulations of stratified rocks rest, are such as from all their characters appear to have been produced by igneous agency. These granitic, hypersthenic, &c. rocks are crystallized like the products of fire, composed of minerals like those observed to be generated by heat, and combined in a very similar manner. They show no action of water, either chemical or mechanical, nor contain the reliquæ of living beings. The almost universal extent of these rocks, combined with the abundance of their disintegrated materials in the older strata, proves the great extent of the igneous agency developed in the earliest eras definable by Geologists.

Influence of  
heat on  
primary  
strata.

The same inference of a pervading and powerful development of heat in those early periods, may be safely drawn from a consideration of the generally high degree of solidification among the primary strata, and their frequent though imperfect crystallization. There is little doubt, or rather the Geologist of sufficient observation considers it a matter of certainty, that the crystallization of primary limestone, the conglutination of gneiss and quartz rocks, and the rhomboidal fissures of slate, are due to the same cause as the conversion of chalk into such limestone, the induration and semifusion

of sandstones, and the prismatizing of shale by the action of basalt, and by the heat of a furnace; and it is certain from various facts that these characters were acquired by the primary strata before the formation of any member of the secondary rocks

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II. Possibly this great and continuous heat beneath the ancient beds of the Ocean, may be admitted as a reason for the paucity of animal and vegetable life during the primary epoch. The fact, however, is that among the older of the primary strata the remains of plants and animals do not occur; and it is probable that the living wonders of Nature were not then in existence. It is, indeed, maintained that such remains would be wholly destroyed in the rocks by the operation of such a heat, and this opinion may be supported by many strong analogies. But as marine organic remains do occur, though rarely, in the midst of the slate group, (Snowdon, Tintagel,) and become numerous in and near the calcareous bands of the upper portion of that series, it appears safer to admit that the heat, or some other unknown condition of this early period, was unfavourable to organic existence in the sea. It seems almost demonstrated that at this period there was very little dry land raised to the surface of the Globe; for all the present Continents were certainly uplifted at subsequent and successive epochs, and therefore land plants could not be abundant.

Organic re-  
mains ab-  
sent from  
the lowest  
primary  
strata;

III. But in proportion as the igneous agency found become frequent in the same ratio as the mountains were uplifted, we find the organic reliquæ of the sea and of the land imbedded in greater abundance. The plants indeed imbedded in coal strata associated with the upper part of the slate series (if really belonging to this system) are local deposits, and not at all to be compared in quantity with several accumulations of later date; but this is also in exact accordance with what is known of the relative extent of land at the different epochs.

It may be objected by those who see in the ancient effects of Nature nothing but the result of the present measure of natural operations, that two-thirds of the Globe are now covered by water, and that the depression of one large tract may have corresponded to the elevation of a smaller, and that remains of plants and animals may occur in the submerged portion of the crust of the Earth, of higher antiquity than any of our elevated strata. This may be true; and it may also be true, as some persons suppose, that stratified rocks full of organic remains occur beneath the granitic floor; but as neither of these hypotheses can be proved or even examined, they must remain as mere speculation.

Objections  
to this hy-  
pothesis  
considered.

But it may also be objected that the whole force of the argument as to the non-existence of organic beings in the earliest primary periods, goes upon the supposition that the primary strata of the same kind are all respectively of the same age, which demands the admission of almost universal formations; and this can never be allowed by those who adopt the existing measure of the effects of the natural agencies employed on the Globe, as a standard for all past periods of time.

No formation now in progress has more than a very limited area and a local character; but this very fact is decisive against the doctrine of the uniform rate and constant momentum of the several agencies of Nature; for no one can consider the wide strata of the chalk and oolite, and the still more expanded saliferous rocks, without being struck by the contrast between them and what we know of the varying bed of the actual seas. But



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these systems of strata, extensively as they are spread over the basin of Europe, appear, when contrasted with the primary strata, mere local deposits. If all the characteristic mountain ranges of the World show themselves composed of these strata, and furnish proof of the superior antiquity of these strata to those which surround the mountain slopes; and contain, though rarely, organic remains which do not exist among superior rocks; if, in short, these latter have the characters of nearly contemporaneous and comparatively recent origin, and the others of nearly coeval ancient date; why are we to reject the plain and obvious inferences from these facts, in order to embrace a narrow speculation, which, by fettering the mind to the results of observation on divided seas, low temperatures at the surface, and diminished heat within the Earth, refuses to consider the results of operations in the wide Ocean, brought on by almost universal chemical and mechanical agencies of heat?

General  
ground of  
argument.

In maintaining the *uniform character* of the natural terraqueous agencies, and the *constancy of their mode of action*, all Philosophers are agreed; but, as in every other problem submitted to investigation, experiment, or observation, the *conditions* are to be determined before the rate and measure of Geological results can be expressed on a scale of magnitude or number. In a Science founded on observation, these conditions cannot be known beforehand, they are the very objects of which we are in quest, and our only mode of approaching them is by analyzing the effects which have been produced by the known laws of Nature, operating under these, at first unknown, conditions. What is the object of an experimental investigation, in which first the law is given, and next the conditions are assumed, the result of their combined operation having been previously defined?

Greater effects of heat in the older Epochs.

A history of the successive revolutions in the state of the Globe, must indeed be founded on a survey of the chemical, mechanical, and vital phenomena now produced by the atmosphere, rivers, the sea, and volcanos; and all conclusions concerning the intensity, duration, and extent of igneous and aqueous agencies, in past Geological periods, must proceed upon an examination and estimate of these agencies in the existing periods; but the ratio of their effects at different periods is to be determined by evidence, not assumed by conjecture.

The results of examination of the organic remains in the several strata, and of the character and condition of these strata, according to their relative antiquity, leave no doubt of the vastly greater and more general influence which, in the older Geological periods, the *proper heat* of the Earth had upon all the operations of Nature in the sea and on the land, an influence far more equable as well as more intense than that exerted by the Solar rays, independent of the Seasons, and coextensive with the Globe.

Surely, then, under these peculiar conditions, the laws of Nature which are concerned in the operation, themselves invariable, must have operated on a greater scale, and perhaps with higher intensity, than that which now characterises their effects.

All the results depending directly on the *quantity* of communicated heat,—as, for instance, most of the phenomena connected with the decomposition, reconstruction,—and consolidation of rocks, must have been vastly increased in amount, and proportioned in extent to the universal diffusion of heat; while the arrangements of

organic life, which we know to be *adjusted to a certain limited range* of temperature, must have been proportionately affected. Until the mean temperature of the sea was reduced to a certain standard, the Physical conditions to which organic life is restricted on our Globe were not established; but during these periods the inorganic forces of Nature must have been especially active, and on a very great scale. Hence the vast thickness, the great degree of consolidation, the crystalline character, the almost universal extent of the primary strata; hence the rarity of organic remains, until, by the accumulation of considerable thicknesses of nonconducting earthy materials upon the bed of the Ocean, the communication of heat from the interior of the Globe was retarded, so as to be counterbalanced by that constant radiation from its surface, which is one of the conditions whereto the organization of plants and animals is adjusted.

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#### *Disturbances of the Primary Strata.*

Though during the accumulation of the slates beneath the waters of the sea, considerable tranquillity and a repetition of similar circumstances prevailed, as may be inferred from the correspondence of the stratification, the rarity of conglomerates, and the general agreement of the organic remains at different points over immense surfaces, yet some remarkable exceptions occur, enough to show that the subterranean forces to which our Continents owe their present forms and elevations, were not wholly inactive. In the Cumbrian mountains, especially, we may clearly perceive the effects of some considerable local disturbance in the conglomerate rock of St. John's Vale, Barrow, and Grasmere; and the singular admixture and blending of porphyries, amygdaloids, and greenstones, with the ordinary argillaceous slates, proves evidently a great and continued development of igneous agency *during* the deposition of the middle slate rocks of the lakes. Similar effects appear to have happened in Snowdonia, and some remarkable cases of extensive disturbance have been ascertained along the Eastward border of the Welsh slate system.

During the accumulation of the slates.

But immediately after the completion of the slate deposit, and before the commencement of the carboniferous system, a much more general and more violent succession of dislocations happened. At this period nearly all the primary ranges of the British Islands received their most remarkable features; and it is deserving of notice that some of the most important of the lines of elevation and depression then produced by subterranean expansion,—for instance, the Grampians, the valley of the Caledonian canal, the Lanimermuir hills, and the prolongation of these ranges in Ireland, the Cumbrian, Snowdonian, and Cornish chains, and the hills of the Isle of Man,—run in the same direction from North-East to South West. This is the most striking example which the British Islands afford in favour of Elie de Beaumont's hypothesis of the accordance between the direction of the axis of a mountain group and the date of its elevation. Elie de Beaumont notices as belonging to the same period as the elevation of the Cumbrian and Cornish chains, the system of the Hunsrück in Westphalia, the country of the Eifel, and the mountains of Nassau, in all of which the principal ranges are North-East by East, and South-West by West. Other examples will hereafter be mentioned which seem irreconcilable to his views; in the mean time we may state that the contemporaneous elevation of the greywacke systems

After the deposit of slates.



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of the South of Ireland and Devonshire ranges East and West. Elie de Beaumont, indeed, distinguishes between the dates of these Eastern and Western lines of elevation, and those previously traced in a North-Eastern and South-Western direction, and refers them to a later period. The North-Eastern lines are considered to have been caused during the transition (slate) period, and the Eastern and Western, immediately after that period. This requires further examination. Professor Sedgwick attributes to the Cambrian slates one great elevation anterior to the carboniferous system, and we may safely adopt this as a general view, though there appears good reason to doubt whether all the various Plutonic rocks mixed in so singular a manner among the conglomerate slates of Cumbria, were injected at one period.

Influence  
on the  
main direc-  
tion of  
strata.

In consequence of these elevations, the strata of slate thrown up towards a central ridge of Plutonic rocks exhibit amidst many irregularities prevailing dips towards the South-East and North-West, and have thus considerably influenced the mean bearing of all the subsequent deposits of British strata in which a very general tendency to the North-Eastern and South-Western direction has been for a long time observed.

Plutonic rocks are often visible along the axis of these ancient elevations. The Cumbrian chain encloses a line of nuclei of granite, syenite, and hypersthene rocks,

besides various porphyries and greenstones in dykes, and overlying plateaux, of which the age is less certainly indicated. These have evidently been injected in a melted state into fissures produced during the general movement of the stony masses; but there is rarely any proof derived from veins, or from the appearances at the points of their contact with other rocks, that the central granitic masses were uplifted in a melted state. But in Cornwall, in the North of Ireland, and still more generally in Scotland, the granitic rocks were evidently in a state of fusion, since the deposit of the slates, and, accordingly, these latter rocks, and the various strata associated with them, are often penetrated by veins of granite, and materially altered at the surfaces of contact. Have the fissures occasioned by these intestine subterranean movements furnished the cavities which have since, by injection, sublimation, and segregation, been filled by various metallic and mineral substances?

These mineral veins are, upon the whole, more numerous in the primary strata than in any of the secondary rocks; and the generally admitted fact that they are not all of the same age in the same mining country, may lead us to suppose that their production was not confined even to one great epoch in Geology, but was repeated at intervals during the whole period of the formation of the strata.

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### Table of the Organic Remains of the Slate System.

The mark \* signifies that the species to which it is attached occurs in the carboniferous system also.

#### PLANTS.

Family.	Name.	Foreign Localities.
Algæ	<i>Fucoides antiquus</i> , Bgt.	Christiana.
	<i>serru</i> , Bgt.	Quebec.
	<i>dentatus</i> , Bgt.	Ditto.
	<i>circinatus</i> , Bgt.	Base of Kinnekulle, Sweden.
Equisetacæ	<i>Calamites radiatus</i> , Bgt.	Bitschweiler. (Haut Rhin.)
	<i>Voltzii</i> , Bgt.	Zundswieher. (Baden.)
Filices	* <i>Sphenopteris dissecta</i> , Bgt.	Berghaupten. (Baden.)
	<i>Cyclopteris flabellata</i> , Bgt.	Ditto.
	* <i>Pecopteris aspera</i> , Bgt.	Ditto.
	* <i>Sigillaria tessellata</i> , Bgt.	Ditto.
	<i>Voltzii</i> , Bgt.	Zundswieher
Lycopodiaceæ	<i>Lepidodendron</i> . (several species.)	Berghaupten, Bitschweiler.
	* <i>Stigmaria ficoides</i> , Bgt.	Bitschweiler.
Class uncertain	<i>Asterophyllites pygmaea</i> , Bgt.	Berghaupten.
	Fossil plants generally	Near Namur.

This list, which is taken almost wholly from M. A. Brongniart's *Prodrome de l'Histoire des Végétaux Fossiles*, will be found remarkably analogous to the more extended catalogue of the plants of the carboniferous system of strata. The fourteen or more species of plants here recorded, belong to genera which occur likewise in the carboniferous strata above, and four of the species, marked by an asterisk, are found again in these rocks. Three of the four occur at Berghaupten, in coal measures which may be of the true carboniferous epoch. All the genera are, probably, extinct, though with respect to the filices this is difficult to prove, on account of the

almost total want of fructification in the fossils, and their generally fragmentary state. Four species are marine, two or three probably belonged to marshes, and seven or eight or more to drier situations. The marine plants are mostly found in limestone. The number of species is too small to furnish, alone, any general inferences either as to the prevalent character of the Flora, or the climate of this period; yet taken in connection with the carboniferous system, they appear to warrant a belief that vascular cryptogamic plants were in possession of the land, that this was very limited in extent, and that the climate was hot.

### Organic Remains of the Slate System.

#### POLYPARIA.

Family.	Name.	British Localities.	Foreign Localities.
Fibrosa	<i>Achilleum carnosum</i>		Groningen. (loose specimen.)
	<i>Manon cribrorum</i>		Eifel.
	<i>Scyphus conoidea</i>		Ditto.
	<i>turbinata</i>		Ditto.
	<i>clathrata</i>		Ditto.
	<i>costata</i>		Ditto.
	<i>Tragos acetabulum</i>		Ditto.
Corticifera	<i>Gorgonia antiqua</i>		Eifel, Ural.

Geology. Ch. II.	Family.	Name.	British Localities.	Foreign Localities.	Geology. Ch. II.
	Corticifera	<i>Gorgonia infundibuliformis</i>		Wipperfurth, Eifel, Ural.	
	Cellulifera	<i>Stromatopora concentrica</i>		Eifel.	
		<i>polymorpha</i>		Ditto, Bensberg.	
		<i>Cellepora antiqua</i>	Glouc. Heref.	Ditto.	
		<i>Retepora prisca</i>		Ditto.	
		<i>antiqua</i>		Ditto.	
		<i>undetermined</i>	Ditto.		
		<i>Millepora</i> , several species		Gottland.	
		<i>Coscinopera placenta</i>		Eifel.	
		<i>Flustra lanceolata</i>		Gottland.	
		<i>Ceropora affinis</i>	Dudley.	Eifel.	
		<i>punctata</i>	Ditto.	Ditto.	
		<i>granulosa</i>	Ditto.	Ditto.	
		<i>oculata</i>	Ditto.	Ditto.	
		<i>disticha</i>	Ditto.	Ditto.	
		<i>fajosa</i>	Ditto.	Ditto.	
		<i>Glaucopora disticha</i>	Ditto.	Ditto.	
		<i>Calamopora</i> , G. {			
		<i>Bromellii</i> , Mün.		Nehou (Manche.)	
		<i>Favosites</i> , Lam. {			
		<i>truncata</i> , Raf.		Kentucky.	
		<i>Kentuckensis</i> , Raf.		Ditto.	
		<i>boletus</i> , Mün.		Christiania.	
		<i>alveolaris</i>		Eifel, Groningen.	
		<i>favosa</i>		Lake Huron.	
		<i>Gottlandica</i>	Douglas near Dublin	Gerolstein, Lake Huron, Catskill Mountains.	
		<i>basaltica</i>		Lake Erie, Eifel, Gottland.	
		<i>infundibulifera</i>		Eifel, Bensberg.	
		<i>*polymorpha</i>		Ditto, Ditto, Pfaffrath.	
		<i>spongites</i>	Shropshire, Dudley.	Eifel, Sweden.	
		<i>fibrosa</i>		Niagara, Kentucky, Eifel, Bensberg.	
		<i>cervicornis</i>		Gottland.	
		<i>Aulopora alecto</i> , Lam. <i>serpens</i>		Eifel, Bensberg, Gottland, Christiania.	
		<i>tubuliformis</i>		Eifel.	
		<i>specata</i>		Ditto, Bensberg.	
		<i>glomerata</i>		Bensberg.	
		<i>elegans</i>		Ditto.	
		<i>sarmentacea</i>		Eifel.	
		<i>Catenopora escharoides</i> , Lam.	Shropshire, Herefordshire, &c.	Ditto, Christiania, Gottland, Lake Huron, Moscow.	
		<i>labyrinthica</i>		Groningen, Drummond Island.	
		<i>tubulosa</i> , Lam.		Christiania.	
		<i>Syringopora verticillata</i>		Lake Huron.	
		<i>ramulosa</i>		Limbürg.	
		<i>reticulata</i>		Ditto.	
		<i>cæspitosa</i>		Pfaffrath near Coln.	
		<i>filiformis</i>		Groningen.	
		<i>undetermined</i>	Glouc. Shrop. &c.		
Lamellifera		<i>Agaricia lobata</i>		Eifel.	
		<i>Swindermana</i>		Groningen.	
		<i>Lithodendron cæspitosum</i>	Glouc. Heref., &c.	Bensberg.	
		<i>Anthophyllum denticulatum</i>		Niagara.	
		<i>bicostatum</i>		Eifel.	
		<i>Cyathophyllum phentum</i>		Kentucky	
		<i>dianthus</i>		Eifel.	
		<i>radicans</i>		Ditto.	
		<i>marguatum</i>		Bensberg.	
		<i>explanatum</i>		Ditto.	
		<i>subnatum</i>			
		<i>hypocrateriformis</i>		Eifel.	
		<i>ceratites</i>		Ditto, Bensberg.	
		<i>flexuosum</i>		Eifel.	
		<i>vermiculare</i>		Ditto.	
		<i>secundum</i>		Ditto.	
		<i>lamellosum</i>		Ditto.	
		<i>placenticforme</i>		Ditto.	
		<i>plicatum</i>		Sweden.	
		<i>quadrigenumum</i>		Eifel, Bensberg.	
		<i>cæspitosum</i>		Eifel.	
		<i>hexagonum</i>		Ditto, Bensberg.	
		<i>helianthoides</i>		Eifel, Lake Huron.	
		<i>Strombodes pentagonus</i>		Drummond Island, Lake Huron.	
		<i>Astræa ananas</i>		Gottland.	
		<i>porosa</i>	Glouc. Heref.	Eifel, Bensberg.	
		<i>Columnaria alveolata</i>		Seneca Sea. (New York.)	
		<i>Sarcinula punctata</i> , Park.	Gloucestershire.		
		<i>organum</i>		Gottland.	
		<i>angularis</i> , Fl.	Dudley.		
		<i>Mastrea pentagona</i> , Raf.		Kentucky.	
		<i>Pleurodictyum problematicum</i>		Nassau, Hunderuck.	
		<i>Hydnophora</i>	Shropshire.		
		<i>*Amplexus coralloides</i> , Sow.			
		<i>Cyathoph. flexuosum</i> ? Goldf.		Mont Chatou, near Coutances, Catskill Mountains.	

In the above list the specific names are chiefly adopted from Goldfuss.

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The great number and variety of the species of polyparia in strata so near in position to those which contain no traces of living Beings, is remarkable, and sets in a strong light the error of those who suppose the paucity or deficiency of organic remains in the lower strata is owing merely to their antiquity; while at the same time the almost exclusive limitation of these remains to the calcareous beds of the slate system shows that the true cause both of their rarity in the one case, and their plenty in the other, must be sought in the condition of the sea at the different periods. It is especially worthy of notice, that though nearly all the species are peculiar to the slate system, most of the genera are repeated in the carboniferous limestone above, and several exist in the present sea, as madrepora, astraea, cellepore, retepora, gorgonia.—Types of all the most remarkable living tribes of polyparia are preserved in these ancient repositories; the lapelliferæ bear the same large proportion to the other corals as now obtains in hot seas, and it is evi-

dent that the general arrangements of Nature with respect to the life of marine animals were of the same kind as at present.

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With respect to the Geographical distribution of the species our Catalogues and our Collections appear to present a remarkable contrast; for while the former seem to show that a very few species only have been recognised at more than one locality, the general impression derived from a view of the latter is exactly the reverse. The systematist is perhaps too easily led to multiply distinctions without necessity, while the eye of the ordinary observer is more easily imposed on by the analogy of kindred forms. At all events, it is certain that the zoophytes of this limestone are eminently characteristic of it, and some of the genera may almost be taken to represent it: such are favosites, catenipora, amplexus, and yet these all occur (less abundantly) in the carboniferous limestone.

## Organic Remains of the Slate System.

## RADIARIA.

Family.	Name.	Rock.	British Localities.	Foreign Localities.
Crinoidea.	Pentremites florealis, G.	Calcareous.	.....	Mississippi.
	Caryocrinus .....	.....	.....	North America.
	Eugeniocrinus mesophiformis, G.	Ditto	.....	Eifel.
	Pentacrinus priscus, G.	Ditto	.....	Ditto.
	Platycrinus ventricosus, G.	Ditto	.....	Ditto.
	*pentagonalis, .....	Ditto	Dudley, Din waur.	
	Cyathocrinus tuberculatus .....	Ditto	Dudley.	
	*rugosus .....	Ditto	Shropshire	Oeland, Dalecarlia, Eifel.
	geometricus, G. ....	Ditto	.....	Eifel.
	pinnatus, G. ....	.....	.....	Ditto.
	pentagonus, G. ....	.....	.....	Groningen.
	Actinocrinus moniliformis .....	Ditto	Dudley.	
	*30-daetylus .....	.....	.....	Eifel.
	laevis .....	.....	.....	Ditto
	cingulatus, G. ....	.....	.....	Ditto
	mucatus, G. ....	.....	.....	Ditto.
	nodulosus, G. ....	.....	.....	Ditto.
	moniliferus, G. ....	.....	.....	Ditto.
	Melocrinus hieroglyphicus, G. ....	.....	.....	Ditto.
	gibbosus, G. ....	.....	.....	Ditto.
*Rhodocrinus	verus .....	.....	Dudley	Ditto.
	pyratus, G. ....	.....	.....	Ditto.
	5-partitus, G. ....	.....	.....	Ditto.
	emuliculus, G. ....	.....	.....	Ditto.
	crenatus, G. ....	.....	.....	Ditto.
	Cupressocrinus crassus, G. ....	.....	.....	Ditto.
	gracilis, G. ....	.....	.....	Ditto.
	tesseratus, G. ....	.....	.....	Ditto.
	Eucalyptocrinus rosaceus, G. ....	.....	.....	Ditto.
	Echinoplærites pomum, W. ....	.....	.....	Oeland, Kinnekulle, near St. Petersburg.
Echinoplærites	aurantium, W. ....	.....	.....	Mosseburg, Westrogothia.
	granatum, W. ....	.....	.....	Oeland, Dalecarlia.
	Wahlenbergii, E. ....	.....	.....	Gulf of Christiania.
	Encrinurus Gothlandicus, W. ....	.....	.....	Gottland.

In the preceding list of radiaria, all the species named by other authors than Miller, have the initials of those authors, as Goldfuss, Wahlenberg, Esmark. The thirty-four species here collected have all vanished from the present ranks of Creation, but we find at least four repeated in the carboniferous limestone. Six of the thirteen genera are also continued into that limestone, and two,

(eugeniocrinites and pentacrinites,) the latter of which is unknown in carboniferous limestone, are rather plentiful in the oolitic rocks. The crinoidea of the slate system are almost exclusively found in limestone, and only locally distributed in that rock. No true echinida or stellerida have yet been described from these ancient rocks.

## Organic Remains of the Slate System.

## CONCHIFERA.

Family.	Name.	British Localities.	Foreign Localities.
Plagymyona.	Trigonia sulcata, G. ....	.....	Lindlar.
	concentrica, G. ....	.....	Ditto.
	undetermined, Ph. ....	Near Kirby Lonsdale.	
Cardium costellatum, Mûn. ....		.....	Elberseuth, Prague.

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	Plagmyona	Cardium hybridum, M.		Elbersreuth.	
		lineare, M.		Ditto.	
		priscum, M.		Ditto, Prague.	
		striatum, M.		Elbersreuth.	
		*aleforme, Sow.	Plymouth, Newton Bushel.	Eifel.	
		costellatum, M.		Elbersreuth.	
		gracile, M.		Ditto.	
		plicatum, M.		Ditto.	
		tripartitum, M.		Ditto.	
		fasciculatum, G.		Kemmenau. (Ems.)	
		marginatum, G.		Ditto.	
		carpomorphum, Dalm.		Sweden.	
		Isocardia Humboldtii, Hæn.		Wissenbach, near Dillenburg.	
		Venericardium retrostriatum, v. Buch.		Martenberg. (Waldeck.)	
		*Crassatella obsoleta, G.		Wipperfürth.	
	Lucina	*pyracina, G.		Eifel, Bensberg.	
		*lineata, G.		Ditto.	
		rugosa, G.		Ditto.	
		*cincta, G.		Ditto.	
		Tellina obliqua, G.		Kemmenau.	
		Cyprina minuta.		Eifel.	
		Corbula zonaria.		Ditto.	
		Cytherea Okem, M.		Regnitzlosau.	
		inflata, M.		Ditto.	
		Hisingeri, M.		Ditto.	
		elongata, M.		Ditto.	
		bilobata, M.		Ditto.	
		subcylindrica, M.		Ditto.	
		intermedia, M.		Ditto.	
		Sanguinolaria gibbosa, S.		Altenahr.	
		undulata, S.		Siebengebirge.	
		concentrica, G.		Eifel.	
		lamellosa, G.		Ditto.	
		dorsata, G.		Ditto, Altenahr.	
		truncata, G.		Ditto.	
		phaseolina, G.		Ditto.	
		solenoides, G.		Siebengebirge, Altenahr.	
		Pholadomya radiata, G.		Eifel.	
		Solen *pelagicus, G.		Ditto.	
		vetustus, G.		Ditto.	
		*Megalonotus cucullatum, S.	Newton Bushel.	Pfaffiath.	
		Modiola Goldfussii, Hæn.		Eifel.	
		antiqua, G.		Ems.	
		Gothlandica, Hs.		Gottland.	
		Mytilus vetustus, G.		Dillenburg, Upper Canada.	
		Arca *præca, G.		Kloster Bruck. (Sollingen.)	
		Nucula antiqua, G.		Harz, Ems.	
		*subnoides, G.		Ditto.	
		foenicata, G.		Olpe.	
		secumiformis, G.		Ems.	
		pungus, G.		Ditto.	
	Mesomyona	Aptychus antiquus, G.		Geistlicher Berg. (Herborn.)	
		lævigatus, G.		Eifel.	
		Avicula obsoleta, G.		Abendtheuer. (Hundsruok.)	
		lepidæ, G.		Geistlicher Berg.	
		Pterinea ventricosa, G.		Kemmenau, Altenahr.	
		costata, G.		Ems, Siebengebirge.	
		lineata, G.		Kemmenau.	
		lamellosa, G.		Siegen, Harz.	
		reticulata, G.		Iserlohn.	
		radiata, G.		Ditto, Eifel.	
		arinata, G.		Pfaffendorf, (Coblenz,) Oneida, N. A.	
		plana, G.		Kemmenau.	
		trigona, G.		Ditto.	
		Posidonia Becheri, Bron.		Geistlicher Berg, Ründeroth, Frankenberg, Werden.	
		longitudinalis, B.		Edderbringhausen. (Frankenberg.)	
		Pecten grandævus, G.		Geistlicher Berg.	
		oceanus, G.		Harz.	
		Neptuni, G.		Eifel.	
		primævus, G.		Wissenbach.	
		Münsteri.		Ditto.	
		undetermined, Phil.	Near Kirby Lonsdale.		
		Gryphaea undetermined, P.	Ditto.		
		Plagiostoma? or pterinea? unde- termined, P.	Ditto.		
	Brachiopoda	{ Producta, S.			
		{ Leptæna, Dal.	depressa, S.	Dudley, Plymouth	Eifel, Gottland, Lithuania.
		*scotica, S.			Eifel.
		*hemisphærica, S.			Ditto, Catskill Mountains, Albany, Lexington.
		rostrata, S.			Bensberg.
		*sulcata, S.			Catskill Mountains.
		anomala, S.	Plymouth		

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Family.

Brachiopoda ...

{ Producta, Sow.  
Leptaena, Dal.

Name.

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sarcinulata, G.	.....	Eifel, Catskill Mountains.
lata, v. Buch.	.....	Sweden ? (found at Güstrow.)
euglypha, D.	.....	Eifel, Gotthard.
rugosa, D.	.....	{ Ditto, Ditto, Catskill Mountains, Oeland, Schonen, Dalecarlia.
transversalis D.	.....	{ Gotthard, Oeland, Schonen, Dalecarlia, East and West Gotthard.
deflexa, D.	.....	East Gotthard.
echinata, D.	.....	.....
aculeata ? S.	.....	Gotthard.
convoluta, G.	.....	Eifel.
furcata, G.	.....	Ditto.
capitata, G.	.....	Ditto.
striata, G.	.....	Coblenz.
pectinata, G.	.....	Eifel, Coblenz, Kaisersuhl.
minuta, G.	.....	Eifel.
*scabricula, S.	.....	Ditto.
Orthis, pecten, D.	.....	{ Ditto, Borenschult, East and West Gotthard, Cata- kill Mountains, Wipperfurth.
*striatella, D.	.....	Gotthard, Lithuana.
zonata, D.	.....	Borenschult.
callactes, D.	.....	Husbyfjel, Ulanda, West Gotthard.
calligramma, D.	.....	Skarpasen, East Gotthard, Trentonfalls
testudinaria, D.	.....	Borenschult, Blankenheim, Trentonfalls.
basalis, D.	.....	Gotthard.
elegantula, D.	.....	Ditto.
demissa, D.	.....	Oeland.
novem radiata, D.	.....	Ditto.
radiata, D.	.....	Eifel.
costata, D.	.....	Kentucky.
rugosa, Raf.	.....	Lake Huron.
granulosa, G.	.....	Catskill Mountains.
fasciculata, G.	.....	Eifel.
undulata, G.	.....	Albany.
nodosa, G.	.....	Eifel.
Deltthis, D.	.....	.....
Spirifera, S.	*minima, S.	Blankenheim.
*attenuata, S.	.....	Eifel, Coblenz
*obtusca, S.	.....	Plymouth.
*rotundata, S.	.....	Newton Bushel.
*lineata, S.	.....	Dudley.
*distans, S.	.....	Plymouth.
*reticulata, S.	.....	Ditto.
*pentagona, S.	.....	Ditto.
*cuspidata, S.	.....	Ditto.
elevata, D.	.....	Eifel, Bensberg, Coblenz.
*labra, S.	.....	Ditto.
alata, S.	.....	Coblenz.
*ambigua, S.	.....	Blankenheim.
*decurrens, S.	.....	Newton Bushel.
*distans, S.	.....	Plymouth.
*oetoplicata, S.	.....	Ditto.
crispa, D.	.....	Gotthard, Eifel.
exporrecta, W.	.....	Gotthard.
trapezoidalis, Hs.	.....	Ditto, Pfaffath, Eifel.
cyrtana, D.	.....	Gotthard, Eifel, Bensberg
subsulcata, D.	.....	Oeland.
*ptychodos, D.	.....	Gotthard.
cardiospermiformis	Dudley	Ditto.
pugio, H.	.....	Ditto.
psittacea, W.	.....	Dalecarlia.
jugata, W.	.....	Ditto.
*la-vicosa, G.	.....	Bensberg, Eifel, Coblenz.
microptera, G.	.....	Eifel, Alleghany, Siebengebirge, &c.
triangularis, S.	.....	Bensberg.
compressa, G.	.....	.....
heteroclyta, G.	.....	Eifel.
macroptera, G.	.....	Catskill, Coblenz, Eins, &c.
leptoptera, G.	.....	Eifel, Landlar.
pachyoptera, G.	.....	Hudson. (New York.)
canulifera, G.	.....	Bensberg.
canaliculata, G.	.....	Ditto.
*striatula, G.	.....	Ditto, Eifel, Christiania, Trentonfalls, &c.
Pentamerus Knightii et	.....	.....
Aylesfordi, S.	.....	Yeo Edge, Downton, &c. Eifel.
levis, S.	.....	Near Ludlow.
Gypidia conchidium, D.	.....	Gotthard, Lithuana.
gryphoides, G.	.....	Pfaffath.
levis, G.	.....	Ditto.
Strygocephalus Burtini, Desf.	.....	Bensberg, Eifel.
striatus, G.	.....	Eifel.

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	Brachiopoda	Atrypa, Dal.		Eifel, Bensberg, West Gottland, &c.	
		Terebratula, Sow.	affinis, S. . . . . Dudley, Plymouth, Ledbury.		
		aspera, Schl.		Eifel, Bensberg, Gottland, Christiania.	
		canaliculata, D.		Oeland, Lithuania.	
		galeata, D.		Eifel, Gottland.	
		nucella, D.		East Gottland.	
		crassirostris, D.		West Gottland.	
		lenticularis, D.		Oeland, West Gottland, Andrarum.	
		casimidea, D.		Gottland.	
		dorsata, His.		Oeland.	
		prunum, D.		Gottland.	
		tumida, D.		Ditto.	
		tumidula, His.		Ditto.	
		micula, D.		Schonen.	
		nitida, G.		Lake Simcoe	
		Terebratula *Ateralis, S.		Eifel.	
		* crumena, S.		Ditto, Lake Huron, Lirdi.	
		* pugnax, S.	Plymouth	Eifel.	
		* Mantia, S.		Ems.	
		* acuminata, S.		Eifel.	
		punctata, S.	Newton Bushel.		
		* platyloba, S.	Plymouth.		
		Hennahana, S.	Ditto.		
		gigantea, S.	Ditto.		
		rotundata, S.	Ditto.		
		lachryma, S.	Ditto.		
		triloba, G.		Eifel.	
		canaliculata, G.		Ditto.	
		quiquelatera, G.		Ditto.	
		dichotoma, G.		Ditto.	
		pentagona, G.		Ditto.	
		Wahlenbergii, G.		Ditto.	
		subglobosa, G.		Ditto.	
		bifida, G.		Ditto.	
		clavata, G.		Ditto.	
		amygdala, G.		Ditto.	
		concentrica, Brown.		Ditto.	
		heterotypa, Brown.		Ditto.	
		* plicatella, D.	Plymouth	Borenshult, Husbytoft, East Gottland.	
		lacunosa, Wahl.	Herefordshire.	Porsgrund, (Norway.)	
		* duodonta, D.		Eifel, Gottland.	
		eumcata, D.		Gottland.	
		bidentata, His.		Ditto, Djupstoken.	
		marginalis, D.		Klutenberg, Gottland.	
		didyma, D.		Gottland.	
		Calceola sandalina, Lam.		Eifel.	
		Crania prisca, Hen.		Rattingen (in greywacke.)	
		Orbicula concentrica, v. Buch.		Martenberg (Waldeck.)	
		rugata, Murchison	Herefordshire, Kirby Lonsdale		
		Langula undetermined, Murchison	Herefordshire		

All the leading divisions of living conchifera are recognised in the shells of the slate system, but there is a singular contrast between the present and the ancient systems, as to the relative proportions of these divisions. A short tabular comparison will render this very evident.

Of 100 conchifera now living 80 are plagymyonous; 18 mesomyonous; 2 brachiopodous: belonging to the slate system, 27 are plagymyonous; 11 mesomyonous; 62 brachiopodous. Of 78 species belonging to plagymyona and mesomyona, 3 are repeated in carboniferous limestone, and 10 of the 11 genera which include them are continued through a long range of secondary rocks.

Nearly all the genera (as yet imperfectly understood) of the brachiopodous bivalves are also found abundantly in carboniferous limestone. Of all these, terebratula is the only one now living, and it is very correct to say that the forms of these "primary" species recede much more from the living terebratula than do those of the less ancient secondary strata. The muscular and ligamental structure of these animals, could it be well made out, would surely afford very curious results. The shells are most frequent in the limestones, but not by any means confined to them. Of 129 species included in the preceding lists, 17 occur also in the

carboniferous limestone, and for the most part abundantly. The localities in which these shells are stated to occur in transition limestone are, Plymouth, Newton Bushel, and Torquay in Devonshire, 10 species; Isle of Man, 2 species; Herborn, Blankenheim, and the Catskill Mountains. We must leave it to future observers to say, whether any other such coincidences occur at these and other places, and whether it is quite certain that the limestones of Devonshire really belong to the transition series, a point on which we cannot avoid feeling some doubt.

The following conchifera, chiefly collected by Mr. Weaver from limestone in the South of Ireland, are referred by M. De la Beche to the transition limestone. We have found in comparing this list with that of fossils indubitably belonging to the carboniferous epoch, so extraordinary an identity, and on the other hand, when compared to characteristic fossils of transition limestone obtained from Countries in which its Geological relations are certain, so marked a discordance, that we must for the present keep the fossils from the South of Ireland separate.

Isocardia \*obliqua.  
Spirifera \*cuneolata.  
\*glabra.

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*Spirifera* \**obtusa*.  
\**striata*.  
\**pinguis*.  
reticulata.  
\**crumena*.  
Terebratula \**cordiformis*.  
\**pugnus*.  
\**rostrata*.  
†*affinis*.  
\**laevigata*, Sch.  
\**elongata*, Sch.  
\**acuminata*.  
\**lateralis*.

Terebratula \**reniformis*.  
Producta \**Scotica*.  
\**Martini*.  
\**concinna*.  
\**lobata*.  
\**punctata*.  
\**fimbriata*.  
†*depressa*.  
*anomala*.

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In the above list the species marked \* are common fossils in the carboniferous limestone, those marked † are usual in transition limestone.

## GASTEROPODA

Family.	Name.	British Localities.	Foreign Localities.
ostiomata	Patella ? <i>conica</i> , W.	.....	Kinneville.
	<i>pennicostes</i> , W.	.....	Ulanda.
	<i>concentrica</i> , W.	.....	Mösseberg.
	<i>Neptuni</i> , G.	.....	Eifel, Olpe.
	<i>primigena</i> , G.	.....	Pfaffath.
Pileopsis	* <i>vetusta</i> , S.	Plymouth, near Ludlow.	.....
	<i>prisca</i> , G.	.....	Eifel.
	<i>compressa</i> , G.	.....	Ditto.
	<i>Sigaretus</i> ? <i>rugosus</i> , G.	.....	Ditto.
Nerita	<i>subcostata</i> , G.	.....	Pfaffath, Ems.
	* <i>spirata</i> , S.	Ditto.	.....
Delphinula ?	<i>aquilatera</i> , W.	.....	Gottland, West Gottland.
	<i>obvallata</i> , W.	.....	Dalecarlia, Oeland.
	<i>cornu arietis</i> , W.	.....	Gottland.
	<i>alata</i> , W.	.....	Ditto.
Tuomphalus	<i>subcuculata</i> , His.	.....	Ditto.
	<i>angulosus</i> , S.	Bentham Edge.	.....
	<i>discors</i> , S.	Shropshire, Dudley.	.....
	* <i>nodosus</i> ? S.	.....	Eifel, Bensberg.
	<i>rugosus</i> , S.	Colbrook Dale.	.....
	* <i>catillus</i> , S.	.....	Lake Erie.
	<i>funatus</i> , S.	Shropshire, Ledbury, Dudley.	.....
	<i>apinosus</i> , G.	.....	Bensberg.
	* <i>laevis</i> , G.	.....	Ditto.
	<i>radiatus</i> , G.	.....	Eifel.
	<i>striatus</i> , G.	.....	Ditto.
	<i>articulatus</i> , G.	.....	Ditto.
	<i>depressus</i> , G.	.....	Ditto.
	<i>Delphinuloides</i> , G.	.....	Bensberg, Eifel, Dillenber.
	<i>trigonalis</i> , G.	.....	Bensberg, Eifel.
	<i>carinatus</i> , G.	.....	Ditto, Ditto.
	<i>angulatus</i> , W.	.....	Gottland.
Cirrus	<i>substriatus</i> , His.	.....	Ditto.
	<i>centrifugus</i> , W.	.....	Dalecarlia, Wikarby, Gottland.
	<i>costatus</i> , His.	.....	Gottland.
	* <i>acutus</i> , S.	Plymouth, Tutworth.	.....
	<i>exaltatus</i> , G.	.....	Eifel.
	<i>ellipticus</i> , His.	.....	Dalecarlia.
Turbo	* <i>tiara</i> , S.	Plymouth.	.....
	<i>bicarinatus</i> , W.	.....	Wikarby, Dalecarlia, Borensb, &c.
	<i>armatus</i> , G.	.....	Eifel.
	<i>nodosus</i> , G.	.....	Ditto.
	<i>Pleurotomaria striata</i> , S.	.....	Ems.
	<i>cirriformis</i> , S.	Ditto.	.....
Turbo	<i>caelatus</i> , G.	.....	Eifel.
	<i>porcatus</i> , G.	.....	Bensberg.
	<i>Kotella helicinaeformis</i> , G.	.....	Pfaffath, Eifel.
Turritella	<i>cingulata</i> , His.	.....	Gottland.
	<i>bilineata</i> , G.	.....	Bensberg, Pfaffath, Eifel.
	<i>coronata</i> , G.	.....	Pfaffath.
	<i>abbreviata</i> , S.	Newton Bushel.	.....
	<i>spinosa</i> , S.	Ditto, Plymouth.	Bensberg.
	<i>striata</i> , G.	.....	Eifel.
	<i>obsoleta</i> , G.	.....	Ditto.
Piasianella	<i>ventricosa</i> , G.	.....	Ditto.
	<i>buccinoides</i> , G.	.....	Ditto.
	<i>fusiformis</i> , G.	.....	Ditto.
solenostomata	<i>Murex</i> ? <i>harpula</i> , L.	Plymouth, Newton Bushel.	.....
	<i>Brucium</i> * <i>acutum</i> , S.	Plymouth.	Bensberg, Pfaffath.
	<i>imbricatum</i> , S.	Plymouth, Newton Bushel.	Bensberg.
	<i>breve</i> , S.	Newton Bushel.	.....
	<i>arenatum</i> , Schl.	.....	Ditto.
	Terebra * <i>Hennahiana</i>	Plymouth.	.....

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Family.	Name.	British Localities.	Foreign Localities.
Monothalamia. . . . .	Bellerophon *tenuifascia, S. . . . .	Newton Bushel.	
	*cornu arietis, S. . . . .		Catskill Mountains.
	*apertus, S. . . . .		Eifel, Plattsburg.
	*costatus, S. . . . .	Plymouth.	Lithuania.
	undulatus, G. . . . .		Blankenheim.
	striatus, G. . . . .		Ditto, Bensberg.
	Hupachii, Def. . . . .		Pfaffrath.
	Caucasicus, Fischer. . . . .		Moscow.
	cicatratus, F. . . . .		Ditto.
	helicoidea, F. . . . .		Ditto.
	nodulosus, G. . . . .		Bensberg, Harz.
Polythalamia. . . . .	Conularia *quadrirulcata, S. . . . .	Gloucestershire	Canada.
	*teres . . . . .		Lochport, Eifel.
	pyramidata, Hbn. . . . .		May near Caen.
	Orthis cinctum, S. . . . .	Herefordshire.	
	circulare, S. . . . .	Dudley, Herefords.	Plymouth.
	annulatum, S. . . . .	Salop.	Eifel.
	striatum, S. . . . .		Malmoë, Christiania, New York.
	granatum, S. . . . .		Elbersreuth, Eifel.
	undulatum, S. . . . .		Tzarkos-zelo. (St. Petersburg.)
	acuarum, M. . . . .		Elbersreuth.
	regulare, Sch. . . . .		Oeland.
	striato punctatum, M. . . . .		Elbersreuth.
	cingulatum, M. . . . .		Ditto.
	torquatum, M. . . . .		Ditto.
	*Stenhausii, S. . . . .		Ditto.
	carinatum, M. . . . .		Ditto.
	lineare, M. . . . .		Ditto.
	irregulare, M. . . . .		Ditto.
	commune, W. . . . .		In Sweden common.
	duplex, W. . . . .		Kimmekulle, New York.
	trochleare, Dal. . . . .		Solleröe (Dalecarlia.)
	centrale, D. . . . .		Ditto.
	turbinatum, D. . . . .		Oeland.
	gracile, Blum. . . . .		Geistlicher Berg, Wissenbach.
	rectum, Bosc. . . . .		Kuchel. (Prague.)
	excentricum, G. . . . .		Bensberg, Gladbach.
	nodulosum, G. . . . .		Eifel.
	imbricatum, W. . . . .		Gottland.
	angulatum, W. . . . .		Ditto.
	lineatum, His. . . . .		Ditto.
	striolatum, V. Meyer. . . . .		Geistlicher Berg, Frankenberg.
	inflatum, G. . . . .		Eifel, Gottland, Lake Huron.
	Cyrtoceras semilunare, G. . . . .		Bensberg.
	depressum, G. . . . .		Eifel.
	compressum, G. . . . .		Ditto.
	ornatum, G. . . . .		Bensberg.
	annulatum, G. . . . .		Eifel.
	lineatum, G. . . . .		Ditto.
Polythalamia . . . . .	Spirula compressa, G. . . . .		Falbach. (Dillenburg.)
	nodosa, G. . . . .		Eifel.
	costata, G. . . . .		Ditto.
	annulata, G. . . . .		Ditto.
	carinata, G. . . . .		Ditto.
	dorsata, G. . . . .		Ditto.
	constricta, Fr. . . . .		Montmorency Falls.
	Nautilus divinus, M. . . . .		Geistlicher Berg.
	intermedius, M. . . . .		Hof Schleitz.
	ovatus, S. . . . .		Ditto.
	Lituites perfectus, W. . . . .		Mosseberg, Reval.
	imperfectus, W. . . . .		Junghy. (Sweden.)
	undescribed . . . . .	Herefordshire, Yorkshire.	
	Ammonites (Goniatites) . . . . .		
	A Gon. expansus, v. B. . . . .		Geistlicher Berg.
	evexus, v. B. . . . .		Eifel.
	Noeggerathi, G. . . . .		Ditto, Wissenbach.
	subnautilinus, Sch. . . . .		Wissenbach.
	primordialis, Sch. . . . .		Harz, Goslar.
	Becheri, G. . . . .		Dillenburg.
	priscus, G. . . . .		Ditto.
	antiquus, G. . . . .		Ditto.
	Heninghausii, v. B. . . . .		Bensberg.
	Munsteri, v. B. . . . .		Elbersreuth.
	simplex, v. B. . . . .		Goslar.
	multiseptatus, v. B. . . . .		Eifel.
	inacquistriatus, M. . . . .		Elbersreuth.
	semistriatus . . . . .		Ditto.
	speciosus, M. . . . .		Ditto.
	retrosus, v. B. . . . .		Martenberg. (Waldeck.)
	Dalmanii, His. . . . .		Gottland.

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The mollusca of the slate system range themselves under 16 gasteropodous and 8 cephalopodous genera. There are stated to be 64 species of the former and 79 of the latter. The gasteropodous genera are mostly thought to be identical with those now in existence; excepting nautilus, all the cephalopoda are extinct generically. All the species are extinct, though *N. caurena*, Lam., is (we suppose by mistake) quoted as found in America.

The ammonites of this system are of the same generic types as those in the carboniferous limestone, with waved or angulated, but not foliaceous sutures.

From the South of Ireland we have,

*Melania constricta*.  
*Pileopsis vetusta*.  
*Nerita*.  
*Cirrus acutus*.  
*Euomphalus catillus*.  
*Plecomaria cirriformis*.  
*Bellerophon tenuifascia*.  
*ovatus*.  
*Orthoceras striatum*.  
*paradoxicum*.  
*Nautilus globatus*.

*Nautilus multicarinatus*.  
*cariniferus*.  
*(Ellipsolites) funatus*.  
*compressus*.  
*ovatus*.

Ammonites.

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In which list the asterisks show analogy to the carboniferous limestone, while perhaps not a single fossil is characteristic of the transition series.

Out of 143 species of mollusca in this list, 16 are marked as also occurring (for the most part plentifully) in the carboniferous system. The localities which produce these shells are the Devonshire limestones before mentioned, Blankenheim, Lake Erie, Shropshire, and the country about New York. We recommend the further consideration of this subject to the special attention of Geologists in connection with Mr. Murchison's recent discoveries in the upper slate system of Wales, in which all his researches appear to show a constant and complete difference between the fossils of the transition series and those of the carboniferous limestone, separated from it by four thousand feet of old red sandstone.

## ANNULOSA.

<i>Serpula epithonia</i> , G. ....	Bensberg.
<i>ammonia</i> , G. ....	Eifel.
<i>omphalodes</i> , G. ....	Michel Dean, Gloucestershire
<i>socialis</i> , G. ....	Ditto. Bensberg.
	Ditto ditto.

## CRUSTACEA.

Family.	Name.	British Localities.	Foreign Localities.
Trilobites.....	<i>Calymene Blumenbachii</i> , Bt. ....	{ Dudley, Tortworth, Charfield, Shropshire .....	{ Ohio, Newport, Utica, Scania, Ostrogottia, Gottland, Eifel, &c.
	<i>macrophthalma</i> , Bt. ....	{ Dudley, Shropshire .....	{ Dusseldorf, Dillenburg, United States.
	<i>variolaris</i> , Bt. ....	{ Dudley, Ledbury, Herefordshire, Shropshire.	
	<i>Tristani</i> , Bt. ....		{ Eifel, Brenville, Falaise, La Hunaudiere, Rennes, Angers
	<i>bellatula</i> , Dal. ....		Husbyfjoel, (Ostrogottland)
	<i>ornata</i> , D. ....		Ditto
	<i>verrucosa</i> , D. ....		Varving, (West Gottland)
	<i>polydora</i> , D. ....		Ljung, (West Gottland)
	<i>actinura</i> , D. ....		Berg, (Ostrogottland)
	<i>schlerops</i> , D. ....		Furudal, (Dalecarlia, Ostrogottland)
	<i>Schlottheimia</i> , Bronn .....		Blankenheim, Daun, Geolstein.
	<i>latifrons</i> , Br. ....		Ditto ditto ditto
	<i>zoncinna</i> , D. ....		Gottland.
	<i>protuberans</i> , D. ....		Westphalia.
	<i>punctata</i> , Wahl .....		Gottland.
	<i>lavigata</i> , G. ....		Gerolstein.
	<i>arachnoides</i> , G. ....		Ditto.
	<i>speciosa</i> , Stensburg .....		Oeland, Rohman
	<i>equalis</i> , Meyer .....		Dillenburg, Herborn.
	<i>Asaphus cordatus</i> , Bt. ....		Gottland.
	<i>caudatus</i> , Bt. ....	Dudley, Ledbury, Tortworth.	
	<i>cornigerus</i> , Sch. ....		St. Petersburg.
	<i>Hausmanni</i> , Bt. ....		Ambresbury, Nehou, Prague, (Siskill Mountains).
	<i>De Buchi</i> , Bt. ....	Llandilo, Bualt .....	Eifel, Cyer, (Norway)
	<i>mucronatus</i> , Bt. ....		Mosseberg, (West Gottland.)
	<i>expansus</i> , Wahl .....	Dudley .....	Sweden, Norway.
	<i>granulatus</i> , Bt. ....		Varving, Olleburg, (West Gottland.) Furudal
	<i>extenuatus</i> , W. ....		Husbyfjoel, Heda, (Ostrogottland.)
	<i>Brongniarti</i> , D. ....		Eifel, May, Nehou.
	<i>angustifrons</i> , D. ....		Husbyfjoel.
	<i>Heros</i> , D. ....		Kinneville, Wikarby.
	<i>platynotus</i> , D. ....		West Gottland.
	<i>frontalis</i> , D. ....		Ljung.
	<i>lanceus</i> , D. ....		Husbyfjoel.
	<i>palpebrosus</i> , D. ....		Ditto.
	<i>crassicauda</i> , W. ....		Ditto, Christiania, Tzarkoselo.
	<i>dilatatus</i> , D. ....		Norway.
	<i>auriculatus</i> , D. ....		Karlstein.
	<i>Bucephalus</i> , G. ....		Eifel.
	<i>armatus</i> , G. ....		Ditto.
	<i>Schroeteri</i> , Schl. ....		Reval.
	<i>velatus</i> , Schl. ....		Ditto.



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of the  
system

In England the carboniferous system, when fully expanded, admits of division into three series :

The old red sandstone,

The carboniferous limestone,

The coal formation ;

and in many parts. (Somersetshire, Monmouthshire, Derbyshire, &c.) these are not only distinguishable but even strongly contrasted ; the first by its red sandstones, and conglomerates derived from the neighbouring primary mountains ; the second by its almost undivided mass of limestone full of marine exuviae ; the last by its shales and argillaceous sandstones, bands of ironstone, and beds of coal. But, in Yorkshire, the limestone series begins to be intermingled with coal, sandstones, and shales ; in the Northern parts of Northumberland these two series are intimately blended ; and in the Island of Arran the diminished deposits of coal and mountain limestone are included, and almost lost in one vast mass of red sandstone, with no clays and conglomerates.

There is nothing peculiar in this : we shall find exactly similar phenomena among the superior formations. In fact, it is certain that among all the formations posterior to the slates, the distinctions of strata are mostly local, and even the formations themselves, however extensive, are limited within the circuit of the anciently elevated primary mountains. Nevertheless, the red conglomerates when present usually appear at the base of the carboniferous system, and the coal deposits are most plentiful at the top. This appears a natural consequence of the state of the Earth's surface when the formation began. The conglomerates should be most abundant in the oldest deposits, because they are evidently the result of the transient violence attending the elevation of the primary strata which they surround ; then, in the sea, the period of succeeding tranquillity is marked by the most decided accumulation of marine spoils ; and these, according as they took place in deep water or near the shore, retain a pure oceanic character, or are mingled with the spoils of the land, which, increasing in quantity, finally buried them under the vast mass of coal measures.

In describing this series we shall confine ourselves principally to the British Isles.

#### *Old Red Sandstone Formation.*

Origin of  
this formation.

In most cases the production of this rock is evidently the effect of general convulsive movements. The slate rocks of Cumbria, exposed upon their recent elevation to enormous waste and degradation, were rolled to pebbles, which were collected into hollows or rude valleys, and reunited by a basis of red sandstone or red marl into vast irregular beds of coarse conglomerate.

The mountains of Scotland are in the same way bordered by enormous accumulations of the same character ; and those of North and South Wales are flanked by extensive deposits of pebbly red sandstone.

This lowest member of the carboniferous system, though varying in character in every different cliff and district, and irregularly distributed, is an extensive and important mass of strata.

In the Cumbrian district.

The limited tract of old red sandstone adjoining to the slate district of Cumberland and Westmoreland, lies principally on the Eastern side, where it appears in patches, in Mell-fell, at Dacre Castle, Sedburgh, and Kirby Lonsdale, and near Kendal. In all these situations it is a very coarse conglomerate, with a basis of red

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sandstone or red marl, filled with fragmented masses, almost entirely derived from the neighbouring slate hills. Some of these fragments are quartz veinstone with micaceous iron ore. Each little patch of conglomerate is nearly confined to a particular valley, and seems, in fact, to have been accumulated by currents which in the ancient times of disturbance passed down that hollow. No organic remains have ever been found in this rock around the district of the Lakes. In some places the quantity of pebbles is diminished, and the red sandstone forms separate beds ; (Shapwells ;) in other places the red clay, alternating with blue and white layers, (as at Kirby Lonsdale,) so closely resembles the new red marl, that nothing but the Geological relations could determine the difference of the deposits. As might be expected in such a heterogeneous mixture, the beds and joints of the conglomerate beds are irregular, and it deserves attention that hitherto no mineral veins have been found to traverse it. Veins of calcareous spar occasionally divide it, and, what is remarkable, the pebbles are often split by these veins, as they are in the contemporaneous conglomerate of Oban in Argyleshire, and the more recent Nagelfluë of Switzerland.

It appears from these circumstances, that during the period of turbulence which succeeded the deposit of the slates in Cumberland, the waters of the sea had a particular tendency to deposit, near the shores, materials charged with red oxide of iron, and that the comparatively quiet process by which sandstones and clays were thus produced was liable to violent interruptions, and the products in consequence mixed with a vast quantity of fragments of the preconsolidated rocks, probably urged downwards to the sea along the lines of dislocated strata which had already begun to be excavated into valleys.

Along the South-Eastern and Southern border of the slate district of Wales, through Herefordshire, Monmouthshire, Glamorganshire, and Pembrokeshire, the old red sandstone formation is much more fully developed than in the lake district of the North. It is vastly thicker, more extensively spread out, composed of various definite parts, and consequently more regularly traceable through the country. Its boundary on the West is by Caermarthen, Brecon, and Leominster. On the East it runs from near Cardiff, by the high district of Wentwood, Trelech, and Craig y Dorth, and by the Forest of Dean, which it encircles with a high boundary edge to near Leominster, where it seems to end abruptly. Its thickness in Monmouthshire and Breconshire can hardly be estimated at less than 2000 feet ; but its lower edge is not always clearly distinguishable from the greywacke slates beneath.

One of the best sections of the old red sandstone is afforded in the neighbourhood of Monmouth, beginning with the Kymm Hill, which is part of the lofty boundary of Dean Forest.

Here we perceive that the thick conglomerate rocks, full of quartz pebbles, remarkably analogous to some varieties of millstone grit, form the very cap of the whole system, and crown the hills with magnificent precipices and solitary crags. Below is a series of red sandstone rocks, productive of excellent flagstone, with one, or perhaps two, beds of a singular limestone, mottled with red, blue, green, and yellow, sometimes much mixed with clays, and always irregular. Though of argillaceous aspect, it is so nearly pure as to be burned to lime ; and though apparently fragmentary, is really a very hard stone, fit for the roads. It contains no organic

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remains. The lowest part of the section exhibits an extreme abundance of red marls with white and green bands, undistinguishable from those of the new red marl.

These characters accompany the range of the old red sandstone through the lower parts of Monmouthshire, and through Herefordshire, and part of Worcestershire, where the upper conglomerates are used as cyder mill-stones, and the limestone (called cornstone) is often employed on the roads.

This limestone, indeed, notwithstanding its apparently irregular and fragmentary character, is one of the most persistent layers that we are acquainted with, for it accompanies and characterises the old red sandstone along nearly its whole course. In Caermarthenshire it is particularly remarkable in the cliffs near Laugharne, from which specimens may be obtained not distinguishable from the "gooseberry" stone of Monmouth.

Scotland

The old red sandstone is largely developed in Scotland, especially along the South-Eastern edge of the Grampian mountains, and on the North-Western side of the slate ranges of Lammernmuir, as fully described by M. Boué. As before observed, it forms in Arran the lower portion of one vast red sandstone series, the upper portion of which, not very different in any of its characters, is taken by Murchison and Sedgwick for the representative of the new red sandstone of England.

On the Western side of Scotland the old red sandstone is found at many scattered points in bays and hollows of the mountains, and has received very good illustration from Macculloch and the Geologists above named. Along the Caledonian Canal and in Caithness, strata of this age abound, and the Orkneys appear to consist chiefly of the same group of rocks.

Almost universally this red sandstone system, how various soever in thickness and in quality of composition, consists in all the lower portion, which rests upon the slate system, of a coarse conglomerate sandstone, generally tinged red, full of fragments large and small, and rounded by attrition in water. This rock does not, like that of Cumberland, to which it is strongly analogous in composition, lie entirely in local hollows, but forms a continuous belt round nearly the whole primary district, where the border of this is distinctly seen, and rises into hills of considerable altitude, which are in this manner wholly composed of the ruins of the interior and still higher primary mountains. The contemplation of this remarkable rock in the vicinity of the beautiful Lakes in the South West part of the Grampians, can hardly fail to impress upon the attentive observer two propositions of the highest importance in Geology. 1st. That the accumulation of these mountainous ruins of earlier rocks was caused by the violence of water, put into activity by the elevation of the primary rocks, and favoured in operation by the fractures which this operation produced in them. 2d. That, since all these effects, the whole region of primary and derivative rocks has been again elevated, perhaps by a more insensible process, so as to raise the conglomerates to the height of 1000 feet or more above the level of that sea in which they were formed.

According to the nature of the primary rocks in its vicinity, as remarked by M. Boué, the red sandstone conglomerate varies in composition. The degree of attrition to which the fragmentary masses which it includes have been exposed, is here different in different places; without doubt according to the degree and continuity of the aqueous action accompanying the disruption of the

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primary strata. Thus on the banks of Lochness, at the Fall of Foyers, we find it a sort of granitoid breccia, with fragments slightly rolled of quartz, mica slate, red granites, primary limestones, &c. We might easily admit that this granitoid breccia is in some degree *metamorphic*, like certain breccias of Plutonic aspect in the slate district of Cumberland. The brecciated character, so remarkable at the Fall of Foyers, is speedily changed at a small distance into the usual aspect of a decided conglomerate.

Along the South-Eastern edge of the Grampians, the composition of the conglomerate appears dependent in a high degree on the nature of the primary series on which it reposes. Near the granitic and porphyritic region of Aberdeenshire, quartz, felspar, porphyry, granite, with garnets, sienite, hornblende, compact felspar, are mentioned by Boué, with gneiss, mica slate, and clay slate. But in the district of Loch Katrine, where Plutonic rocks are less abundant in the slate system, the fragments consist almost wholly of mica and chlorite slate. In Oban we have observed that the rock contains not only masses of trap rocks, but that its base is in places almost wholly composed of the substance of those rocks reduced to sand. Along the Lammernmuir ranges, which are composed of clay slate and trap rocks, the conglomerates contain almost wholly slate fragments and boulders, and lie in hollows of the chain, very much as the contemporaneous deposits border the similar slates of Cumbria.

The inclination of the conglomerate strata is dependent on the configuration of the primary mountains, and there is no doubt that the stratification is for great lengths of country in irregular accordance with that of the older rocks; yet this dependence is chiefly observed along the lines parallel to the axis of elevation of the Grampians, and is even there liable to great exceptions. In the vicinity of Loch Lomond it succeeds clay slate; generally along the Grampians it rests on mica slate or chlorite slate; but along the Lammernmuir hills on grey-wacke slate.

Receding from the border of the mountains, the upper strata of red sandstone are found nearly free from pebbles, composed of laminae of various quality, sandy or argillaceous; and sometimes, as in Perthshire, variously coloured. The greater part of the sandstones of Caithness, which are usually ascribed to this era, are dark, carbonaceous, flagstone rocks, in a few places containing between their layers very interesting specimens of fishes, which have been conjectured to belong to freshwater tribes. Laminated sandstones abound in the Orkneys. Red sandstones accompany the coal of Dumfriesshire, and in this part of Scotland we believe that the red sandstone series is, like that of Arran, a great continuous deposit, in which the carboniferous limestone and coal seams form merely the parting, not always traceable, between the old red and the new red sandstone systems. A natural classification, in all the Southern parts of Scotland, made without reference to other parts of the Island, would, we think, include the carboniferous and saliferous systems in one general term, the red sandstone system having, as subordinate groups, the mountain limestone and coal strata.

This should diminish the anxiety sometimes felt about *universal agreement in classification*, and encourage topographical Geologists to employ for the country they describe the arrangement of strata most suitable to develop the true local relations of the rocks.

Metallic veins are rare in the old red sandstone rocks,

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but veins of crystallized earthy substances occur frequently. Carbonate of lime traverses it at Kirby Lonsdale; sulphate of barytes near Monmouth and South Saunox in Arran; sulphate of strontian occurs in it near Inverness; and asbestos in Kincardineshire. (Bouc.) The joints in it are very irregular.

In Ireland.

The mountain limestone, which underlays all the coal fields of Ireland, generally rests on old red sandstone, which is unconformable to the subjacent slates.

#### *Mountain or Carboniferous Limestone Formation.*

The carboniferous limestone is a rock of which the history must principally be studied within the limits of the British Islands, for it is no where else so much or so variously developed. Its romantic rocks border many of the most beautiful valleys of the South-West of Scotland, Northern and Central England, and encircle the wide primary regions of Wales. In Ireland, as Mr. Weaver observes, this limestone is the prevalent and characteristic rock in most of the Counties, except Derry, Antrim, and Wicklow.

The romantic channel of the Meuse runs for a considerable distance about Namur and Liege in a very remarkable range of carboniferous limestone, along the Northern side of the primary slates of the Ardennes, and is prolonged Eastward to the German side of the Rhine, near Dusseldorf, and continued Westward (beneath a wide deposit of chalk) to the neighbourhood of Boulogne. The coal deposits of Poland are based upon dark limestones of the same age as the carboniferous limestone of England, but in general the coal fields of the centre and South of France, of Saarbruck, of Saxony, Silesia, &c. appear to be devoid of this rock; but Mr. Murchison mentions its occurrence in the North-East of Bavaria and in Bohemia. It abounds in North America, accompanying coal and anthracite.

It has been before remarked, that the carboniferous limestone presents itself with a very different aspect in the Northern and Southern Counties of England. In Somersetshire, Gloucestershire, Shropshire, South Wales, North Wales, Derbyshire, and Leicestershire, this rock appears an immense, nearly undivided, calcareous mass, perfectly defined below by a hard contrast with the old red sandstone or greywacke slate which supports it, and as distinct above by the abrupt covering of sandstones and shales which accompany the coal.

Very rarely indeed in the Southern Counties, as in the rocky valley of the Avon at Clifton near Bristol, are any beds of red sandstone interpolated among the lowest strata of limestone; and it is only by a few unimportant partings of shale that the upper portion is at all assimilated to the incumbent series. The toadstones which irregularly interlamine the thick limestones of Derbyshire are of igneous origin, and it is not, in proceeding Northward, till we arrive in the valley of the Ribble, that any decided alternation of mechanical deposits breaks into distinct groups the strata of carboniferous limestone. From this point Northward, almost in the ratio of distance, to the banks of the Tweed, the limestone becomes more and more divided by beds of sandstone and shale, accompanied by ironstone, fossil plants, and coal; and thus, under Ingleborough we have a nearly undivided calcareous mass 400 or 500 feet thick; but at Aldstone Moor no less than twenty different limestones, amounting altogether to 470 feet, obscured by the interposition of no less than 1686 feet of sedimentary strata.

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Farther North these mechanical admixtures increase in amount, while the calcareous strata diminish, and at length, in the Northern parts of Northumberland, the limestone district has become a valuable coal field.

To embrace the subject in its most interesting point of view, we shall commence our account of the carboniferous limestone with a description of its characters in the "Pennine Alps," which border the Western parts of Yorkshire and Durham, and the Eastern parts of Cumberland and Westmoreland, and we shall connect there with the analogous arches of limestone, which begird the primary district of the Cumbrian lakes. Taking this as a type of the formation, we shall be able to compare with it the other localities in the British Isles and on the Continent of Europe.

This tract of country has been, for different objects, partially described by Professor Sedgwick and other Geologists, and their views, whether published or not, will be recognised in the following summary. The Cumbrian slates are surrounded for three-quarters of a circle, from Egremont to Ulverston, by a belt of limestone, which reposes indiscriminately upon the lower slate near Loweswater, the middle slates near Ulswater, the upper slates from Shap to Ulverston, and the old red conglomerate at the several points of Dacre, Sedburgh, Barbon, Kirby Lonsdale, and Ulverston.

The South-Eastern part of this circular belt forms part of a long range of limestone cliffs facing the West from Ingleborough to Tindal Fell, defined by one continuous line of elevation nearly 1000 yards in height. Prodigious transverse dislocations occur at these points, that at the Northern end ranges East and West, and causes an immense depression to the North, after which the limestones range North-East through Northumberland; that at the Southern end ranges West South-West and East South-East, and causes an equally striking depression to the South, after which the limestones show themselves locally, and in much disturbance, as far South as Clithero.

From the high Western escarpment before mentioned, the strata sink with a very regular inclination Eastward or South-Eastward, and are exposed in the valleys of the South Tyne, Derwent, Wear, Tees, Greta, Swale, Yore, Ribble, Wharfe, Nid, and Aire, bordering those streams with some of the boldest and most picturesque rock scenery in England.

The grand natural section of Ingleborough and Penygant presents us with the following series of rocks belonging to the carboniferous limestone.

	Feet.
1. Group above the limestone, commonly called millstone grit series .....	100
2. Upper belt of limestone .....	78
3. Alternations principally of shales and sandstones, some of them flagstones, with thin limestones .....	300
4. Great scar limestones with calcareous conglomerate beds at bottom .....	400

This series rests on slate rocks.

Proceeding Northward from Ingleborough we arrive in Wensleydale or Yoredale, and find the section modified as under:

Geology. Ch. II.		Feet.		Calcareous beds. yds. ft. in.		Other de- posits. yds. ft. in.		Geology. Ch. II.	
Millstone grit series.		Coarse and fine sandstones, shales, and coal.....		8 0 0		24 2 6			
1. Above the limestone.		Coarse, fine, and slaty sandstones, shales, cherty beds, and coal...							
		Millstone grit of Ingleborough, shales, cherts, and coal.....							
2. Upper limestone belt.		Thin limestone, sandstone, shale...		6 0 0		8 2 6			
		Main or twelve fathom limestone...							
		Shales sandstones and coal, under- set limestone.....		10 1 6		30 0 0			
3. Flagstone system....		Alternations of flagstones of various quality, in great abundance, with shales, coal, hard gritstones, and three or four strata of limestone, from 6 to 30 feet thick. The black marble of Dent is nearly at the base of this group.....		8 1 6		4 0 0			
		Limestones of great thickness, with partings principally of shale.....		7 0 0		7 0 6			
4. Scar limestones.....				44 0 0		4 0 0			
				Alternations and coal.....		8 0 0			
				4 0 0		55 0 0			
				2 1 6		73 2 0			
				6 0 0		78 0 0			
						156 2 0		562 0 2	

The series is incomplete, other limestones existing below.

Here it will be perceived the group No. 4. has become divided into distinct parts; and the calcareous portions of No. 3. are also more defined and more important. No. 2. has assumed that character of a decidedly double belt, which henceforward distinguishes it for a great distance to the Northward.

Our next station will be taken in Swaledale.

1. Millstone grit series.	Coarse gritstones, shales, finer sandstones, shales, and coal.....	600	900
2. Upper limestone belt.	Variable series of thick shales, with sandstones and coal.....	200	252
	and local intercalations of limestone and chert.....		
3. Flagstone system....	Limestone.....	3	340
	Shale, &c.....		
4. Scar limestones.....	Main or twelve fathom lime.....	72	
	Grit, chert, shale, and coal.....		
	Under-set lime.....	18	
	Variable alternations of gritstone, flagstone, and plate, with three or four limestones from 6 to 30 feet thick.....		
	Of great thickness, but only partially exposed in the bottom of Swaledale.....		

The groups 1 and 3 have now become more complicated, and require further division as compared with the Ingleborough section, and thus we are gradually conducted to the still more developed series of Aldstone Moor, as described by Forster.

1. Millstone grit series.	Alternations of sandstone, (coarse and fine) and shale.....	1 1 6	25 1 0
2. Upper limestone belt.	Alternations of laminated and other sandstones, shales, ironstone, and coal.....	3 0 0	109 2 8
	Limestone.....		
	Alternations, plate, &c with coal.	21 0 0	16 2 0
	Limestone.....		
	Purting.....	0 1 6	10 0 0
	Limestone.....		
	Sandstone and shale and coal...	8 0 0	23 1 0
	Under-set limestone.....		
	Sandstone and shale (Nattriss Gill Hazle).....	3 0 0	17 0 0
	Limestone.....		
	Sandstone and shale.....	2 1 6	15 1 6
	Limestone (5 yards).....		
	Sandstone and shale.....	10 0 0	10 0 0
	Scar limestone.....		
	Thin alternations.....	0 2 0	15 0 0
	Cockle-shell limestone.....		
	Alternations.....	2 0 0	5 2 6
	Limestone (single post).....		
	Alternations.....	2 0 0	20 0 0

It is probable that even this section does not show us the full depth of the series.

We have for some time been occupied in endeavours to ascertain *exactly* the line which in the Aldstone section separates the groups 3 and 4 of Yorkshire, and the above result is very near the truth.

Combining together the preceding statements, we have the following results in total thickness:

Group.	Penyngant.	Wensleydale.	Swaledale.	Aldstone Moor.
1. Millstone grit series (incomplete series)	260+	700	800	409
2. Upper limestone belt.	80	200	250	247
3. Alternations, or flagstone system....	300	400	250	304
4. Scar limestones.....	400	250+	120+	1196

In the following table the relative proportions of the calcareous and the other deposits are estimated:

Group.	Penyngant.		Wensleydale.		Swaledale.		Aldstone Moor.	
	Lime-stones.	Other deposits.	Lime-stones.	Other deposits.	Lime-stones.	Other deposits.	Lime-stones.	Other deposits.
1.	260	700	10	790	4	405		
2.	70	100	93	157	97	150		
3.	30	270	50	350	40	210	54	250
4.	400	150 + 100	80 + 40	313	883			
	500	540	300 + 1250 + 223 + 1197 + 468	1688				

We must remark that this comparison is imperfect, because the sections are not in each case defined above or below by the same beds: in order to obtain a fairer numerical comparison, we may omit altogether the beds above the upper limestone belt, and, on account of its incompleteness, the fourth group in Wensley Dale and Swaledale.

We shall then have the following corrected scale:

	Penyngant.	Wensleydale.	Swaledale.	Aldstone Moor.
Upper limestone belt . . . .	70 10	100 100	93 157	97 150
Flagstone system . . . . .	30 270	50 350	40 210	54 250
Scar limestones . . . . .	400 —	— —	— —	313 883
	500 280			464 1283

Had we, instead of Penyngant, chosen Great Whernside for our section, we should have had the limestone of these groups about 100 feet, and the other deposits less than 200 feet; and if we had taken a section in Northumberland, instead of Aldstone Moor, the limestones would have been less than 200 feet, and the other deposits probably nearer 1000 feet. The principal changes, as we proceed Northward, appear to happen in the

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Range of  
the moun-  
tain lime-  
stone.

lower part of the limestone group, which loses its individuality by admitting between its beds a constantly increasing quantity of mechanical admixtures, and at length becomes a subordinate feature in a country which has the characters of a coal field. We shall now trace the course of the carboniferous limestone round the Cumbrian mountains, and through other parts of England.

The lower, or as we shall name it "scar limestone" group, passes Westward from Ingleborough by Kirby Lonsdale, Burton, and Cartmell to Ulverstone and Dalton; extending Northward to Kendal. (See Smith, *Geological County Maps*.) This group every where possesses the almost wholly calcareous character which it bears in Ingleborough. On the South of Ulverstone, it is covered by the intermediate grit and plate series with traces of coal, and a more extensive deposit of this kind South of Kirby Lonsdale, yielding useful coal and flagstone, is again overlaid by the upper belt of limestone and afterwards by the millstone grit series towards Lancaster.

Under Wild Boar Fell, on the borders of Yorkshire and Westmoreland, the scar limestones begin to exhibit, in consequence of dislocations, a double escarpment, the Western branch passes off by Ashfell, Orton, Shap, and Iowther, to the Eamont, and continues by Greystoke Park, Hesketh, Ireby, and Cockermouth to Egremont. These limestones alternate in their lower parts with red sandstone, by some Geologists referred to the old red, and diminish in thickness Westward. They are overlaid by deposits of the grit and shale series near Shap, Hesketh, Newmarket, and Bolton, but from Workington to Whitehaven the thick and abundant coal seams probably belong to the ordinary coal series above the millstone grit. There is, perhaps, unconformity here between the coal measures and the limestone, a case very rarely observed in England.

Agreeably to what has been said before the scar limestones, in passing through Northumberland, become continually more and more subdivided by interpolations of sandstone, shale, and coal, till on the sea-coast North of Belford, a part of this series contains no less than thirteen bands of limestone, (121 feet in total thickness,) separated by many times their thickness of sandstone and shale, and under the whole lie workable seams of coal. The character of the surface of all the Western and North-Western part of Northumberland corresponds to this change of the component strata. Instead of the beautiful green pastures which delight our eyes amidst the calcareous dales of Derbyshire and Yorkshire, wide, heathy, and boggy moorlands overspread the surface of sandstones and shales, and we seem to wander in a region of barren coal measures rather than on the range of the thickest carboniferous limestones. This may serve to explain the seeming anomaly in Mr. Greenough's Map, where this unquestionably carboniferous tract is represented as distinct from any of the strata in the British section. Mr. Smith colours the whole space as a coal tract.

On the contrary, in proceeding Southward along the Ribble, we find the lower scar limestones in great force about Clithero, surmounted by a considerable mass of shales with sandstones, corresponding to the shale and grit series of Ingleborough; above these, in Pendle Hill, appears the diminished upper belt of limestone, and, over all, the millstone grit series, here also occasionally yielding coal. Hence to Derbyshire the scar limestones lie

too deep to be seen, and the upper belt of limestone appears to be extinguished; so that this part of the Western boundary of Yorkshire is occupied by a vast thickness of the millstone grit series and the flagstone series, without any disclosure of the subjacent limestones, even in the deeply excavated valley of Todmorden.

In Derbyshire, putting out of the question the irregular interpolations of igneous rocks, called toadstone, we have the scar limestones more than 750 feet thick, surmounted by shale with their alternations of sandstone, limestone, ironstone, &c. 500 feet, and the hills are crowned by bold ranges of millstone grit, and its accompanying sandstones, 360 feet in thickness.

See pl. i. fig. 15. which expresses in general terms the method of variation of the carboniferous limestone and millstone grit series of the grand Penine chain.

South of Derbyshire we have no longer the same remarkable mass of strata interposed between the scar limestones and the proper carboniferous sandstones and shales. The limestone, wherever it occurs in North Wales, Shropshire, the Forest of Dean, Mendip, and round the coal field of South Wales, refers itself to the type of the scar limestones of Derbyshire, and it is only by a very imperfect representative in Shropshire and the Forest of Dean, and on the Northern border of the coal field of South Wales, that the millstone grit series can be recognised.

The limestone tract along the Meuse is evidently of the same era as the limestone of Derbyshire and Monmouthshire, and continually recalls to the delighted voyager the beauties of the Derwent and the Wye, but the strata above it are with difficulty compared with those of any part of the English basins.

Having thus compared in the most general point of view the component groups of the carboniferous limestone and millstone grit series in different localities, and ascertained the method of variation which it observes, we shall endeavour to describe some of the principal characters of these several groups.

#### Scar Limestones.

The carboniferous limestone, though by no means of one uniform aspect or chemical composition, possesses, nevertheless, a certain range of mineralogical characters which are scarcely to be recognised in any of the other secondary calcareous deposits. It is usually a nearly pure carbonate of lime, of a greyish or even very blue tint, of considerable hardness, and imperfect conchoidal fracture. Some of the varieties are very dark coloured, and even quite black, (Swansea, Abergavenny, Kilkenny, Derbyshire, Yorkshire,) but the latter commonly contain a minute admixture of argillaceous and bituminous matter. Many varieties exhale a fetid odour on being rubbed or bruised. In Derbyshire, and generally along the Yorkshire and Westmoreland ranges, the scar limestones contain considerable beds of a granular and even brecciated limestone capable of being employed as good freestone, and some layers in Derbyshire and Westmoreland appear almost wholly composed of crystalline grains, and contain magnesia. A crystalline variety in Derbyshire is mixed with red oxide of iron. In the country about Burton in Kendal, and Clifton, near Bristol, the stone is often decidedly oolitic, and even exhibits considerable variety in this respect. The lower layers which rest upon the slate on the Craven mountains, at Kendal, and near Penrith, are filled with large and small boulders of the slate, so as to become a real conglomerate.

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But the most decided characters of these rocks are the organic remains, all of which are different from those of the strata above. The prodigious abundance of productæ, spiriferæ, terebratulæ, and other shells, of lamellated corals, and above all, of crinoidal remains, will almost always enable even the tyro to pronounce on the identity of the mountain limestone. Crinoidal remains, in particular, are so excessively abundant in certain parts as to constitute fully three-fourths of the mass of the rock.

Chert beds  
and nodules.

A remarkable character is imparted to vertical sections of this rock in the Mendip hills, in several parts of Derbyshire, and the neighbourhood of Clithero, by nodules of chert imbedded in the limestone, often at regular distances, like the flints in chalk. A very striking section of this kind is seen in Vallus Bottom, near Wells. This chert is usually of a dark grey, or even black colour, but occasionally it is white, and in general its colour corresponds to that of the limestone beds which contain it. It rarely contains any organic nucleus, and thus differs from a large proportion of the flint nodules in chalk, with which, in the manner of its production, and in its relations to the calcareous rocks, it seems otherwise very analogous. The cherty layers in green sand and coralline oolite are also analogous instances and we have hereafter to notice a similar character in a certain portion of the magnesian limestone. Proceeding Northward, as the limestones are divided, these chert nodules are less plentiful, though in Coverdale, in Yorkshire, they abound, and at Glenwhelt, on the Roman wall, shells of the genus *Bellerophon* have been detected in a very dark chert imbedded in the limestone there.

Chert beds.

The curious circumstance of conversion, as the miners say, or rather substitution of beds of chert for beds of limestone, generally at the top of the rock, is noticed in most parts of the limestone tract in England and Wales; and very often it happens, as in Westmoreland, that the corals are converted to silicious matter in the midst of a block of limestone. It is probable that the substance resembling rottenstone of Dentdale, Swaledale, and Aldstone Moor, may be occasioned by decomposition of this chert, but Mr. Farey thinks the rottenstone of Derbyshire is owing to a decomposition or change of the shale limestone near the surface. A specimen collected by the author at Aldstone Moor in 1820, which as to substance is a kind of rottenstone, is evidently decomposed chert, and contains several fossils of the limestone series, especially a very small species of trilobites. Similar facts are common in the Yorkshire dales.

• Bitumen in solid masses lies very frequently in the beds of the scar limestone, and enters the cavities of productæ, orthocærata, &c.; as at Castleton, and near Clithero. • In a liquid as well as solid state it will be noticed under the next division of the carboniferous strata.

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geography.

The surface of the country which is occupied by this rock in England is remarkably characteristic. Having been exposed to many repeated convulsions, it is thrown up to considerable altitudes, and placed in a great variety of positions favourable for the exhibition of the changes wrought on it by the atmosphere and streams. It is principally to the hardness and comparative durability of this rock, conjoined with its stratification and extensive system of joints, that we owe the grand ranges of vertical escarpments, which begird with a perpetual fortification the sides of the dales of Yorkshire and Derbyshire. Often, indeed, the wasting effect of the ele-

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ments is sufficient to excavate vertical rents and to insulate the great prisms of the rock which, especially in Dovedale and other parts of Derbyshire, give the most romantic features to the valleys, while the same effects upon the high scars in Yorkshire and Westmoreland show like towers and bastions projecting from the wall of rocks or among the green herbage which has spread around them.

Frequently upon broad surfaces of limestone, especially where it alternates with shale, we find ourselves suddenly stopped by a deep vertical pit in the rocks, worked by some little rill, or even by the mere gathering of rains, an effect more frequently observed in the course of streams, which, like the Calder in Cumberland, traverse the ranges of this rock. These "swallow holes," as they are justly called, often serve to mark out uninterruptedly for miles the lines of limestones, whose actual edges may be obscured by the sliding of other matter over them.

Swallow  
holes.

These swallow holes sometimes communicate downwards with internal caverns, which are nowhere so abundant as in the lower or scar limestones. It is to them we must refer the numerous caverns of Mendip hills, in Somersetshire, the rocks of Clifton, the Forest of Dean, the celebrated caverns of Staffordshire and Derbyshire, and those beneath Ingleborough and Pen-y-gant, in Yorkshire. Further North, along the Penine chain, where these limestones grow thinner, the caverns become less numerous, and in the same proportion the phenomenon of underground streams is rarely observed. This remarkable phenomenon is evidently dependent on the thickness, as well as on the open joints and absorbent surface of the rock, and examples of the same kind occur in various other thick calcareous strata of England, as the oolites and chalk, as well as in the Jura limestone or oolite of Germany and France. It is to the same causes that we must ascribe the extraordinary strength of the springs which issue as clear as crystal from the openings of this rock: but, being highly charged with carbonate of lime, soon deposit along their channel abundance of tufa. The herbage upon this limestone is usually short, elastic, and nutritious, and of a lovely green, which contrasts strongly with the bluish aspect of the moist surfaces of the shales, and the brown tints of the heathy moorlands of millstone grit.

#### Flagstone Series.

The shale and grit, or flagstone series above the scar limestones, is called in Derbyshire the limestone shale. In Derbyshire. It is about 500 feet thick, and consists principally of black or brown rather durable shale, forming a very wet soil, and causing land slips of great extent beneath the millstone grit summits. Mam Tor, the "Shivering Mountain," near Castleton, exhibits these characters very decidedly. The shale, however, is interstratified to a great extent, and with a considerable regularity, with thick rocks of fine-grained micaceous gritstone, of excellent quality for building, and, as we have observed, generally at the bottom of this rock, with good durable micaceous flagstone, very similar to that in the more recent coal strata. Some less regular sandstone beds, called "Cankstone," approach very nearly to the nature of the gauster or calliard rocks of the coal strata. Mr. Farey, who considers these interpolations as anomalies, calls by the same name the very characteristic beds of black argillaceous limestone which lie in this shale, at Ashford, near Bakewell, and near Ashborne, and produce lime fit for water cement. The frequent contor-



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tions of the limestone and shale are noticed by Mr. Farey as very remarkable. Ironstone balls lie in bands in this shale, a few impressions of fossil plants have been collected, and very thin coal seams observed, not worth the expense of the fruitless trials in search of them. Liquid bitumen is mentioned at several points in connection with the limestones in this shale.

In York-  
shire.

This description of the Derbyshire limestone shale would apply with scarcely a varying sentence to the broad argillaceous strata which cover the thick limestones of Craven. The same abundance of shale, occasional interpolations of sandstone, ironstone, and laminated beds of dark limestone, the same traces of coal and liquid bitumen, the same contortions, may be traced in Craven and in Wharfedale. More divided by sandstones and limestones, the same shale is recognised in Pendle Hill, Ingleborough, and Penygant. The locality most remarkable for the abundance of liquid bitumen is at Flasby in Craven, where Mr. Preston has excavated a considerable quantity of the black argillaceous limestone, and found it associated with abundance of *nautilus sphericus* besides large *orthocera* and the curious fossil formerly supposed to be a *pleurobranchus*. The nautilus are generally inverted or have their cavities filled with liquid bitumen, and small solid lumps of the same substance are likewise met with. This, amongst others, is one strong reason for believing that the darkness of colour of these limestones and shales is due to the admixture of carbonaceous matter.

By a recent communication of Sir Philip Egerton and Lord Cole to the Geological Society, we have learned that the lower coal shale, as it has been termed in the Western Irish coal fields, is precisely analogous not only in mineralogical characters, and in its geological position between the mountain limestone and the true coal measures, but also in its organic remains, to the "limestone shale" of Derbyshire and Craven. The same ammonites, the same *posidonie*, (Broun,) and other characteristic fossils occur in these far separated districts; and in general, so strict is the accordance in all respects, that no Geologist accustomed to the strata of the North of England, could fail to recognise in the mountains above Enniskillen an exact analogy with Ingleborough and Great Whernside.

Penine  
chain.

In the further continuation Northward of this series of shales, sandstones, and limestones, the limestones, as before observed, thicken, the alternations of sandstone and shale therefore become more frequent and divided, coal seams intervene, and the whole assumes the character of a complicated coal and limestone deposit. It is possible, in tracing the different limestones enumerated in this series, to assign characters of local permanence. Thus the beds most remarkably stored with crinoidal reliques, are those of the "main lime," in Pendle Hill, Ingleborough, Cam Fell, &c.; the black limestone of Whalley, Kirby Lonsdale, and Dent, is almost wholly deprived of them, like the same beds in Derbyshire; *productus* abound on the top of the main lime, *caryophyllæ* are often plentiful in the beds below it, and one thin bed of limestone, at Aldstone Moor, receives, in consequence of the nature of its organic contents, the name of Cockleshell Lime. Chert lies frequently on the top of the main lime, and underset or four fathom lime beneath it, as well as on the top of the little lime or crow lime above it. Slaty sandstone yielding flagstone occurs both in the alternations under the main lime, and in those still lower between the underset and scar lime-

stones. In one or other of these places in the section, flagstones are dug in Swaledale and Yoredale, in Graygarth fell, near Kirby Lonsdale, and Garstang, and it is probable that the flagstones of the North of Derbyshire belong to the same epoch. In some of the very hard sandstones which occur in this series in Swaledale, (like the cankstone of Derbyshire,) *stigmariæ* and other fossil plants occur, but in general the coal seams are not accompanied by many vegetable remains.

A kind of rottenstone, as before mentioned, occurs in this series in Dentdale and at Aldstone Moor, and probably in many other places is produced from the decomposition of the chert.

The shales of this tract are usually dark, close, and fissile, and traversed by immensely long straight joints ranging North by West, and South by East, East North-East and West South-West, dividing the rock into rhomboidal prisms. They often contain nodules of ironstone. A very remarkably indurated flinty shale, fit for use on the roads, which occurs in Swaledale and Yoredale above the main limestone, is called "Black beds."

The sandstones vary as to fineness of grain, and some of them in their progress through Northumberland assume such a coarseness of aspect, as to be in fact undistinguishable from the "millstone grit" of the next group.

The marine fossil remains are almost wholly confined to the limestones and the cherts which sometimes replace them, but the few vegetable remains belong wholly to the sandstones and to the coal.

In the Midlothian coal field in the Counties of Edinburgh, Haddington, and Peebles, Mr. Farey sen., in 1816, ascertained 337 principal alternations of strata between the surface in the town of Fisher Row on the banks of the Frith of Forth, (where the highest of these strata occur,) the commencement of the basaltic rocks forming the general floor and border of this important coal field. These strata lie internally in the form of a lengthened basin or trough, and consist of sandstone, shale, coal, limestone, ironstone, &c. 66 seams of coal, counting the double seams as one; 72 assemblages of stone and other sinkings; in all 5000 feet in thickness.

Coal field of  
Midlothian

### Upper Limestone Belt.

The only additional remarks which we shall make on this portion of the strata refer to the remarkable variation of character, by which the limestone in several places is gradually changed to or suddenly replaced by chert. Thus in Swaledale the united thickness of the underset chert and underset lime (the former being uppermost) is nearly constant, but the thickness of each is extremely variable. In like manner in Wharfedale, about Kettlewell, the underset lime just before it expires entirely under Great Whernside, is represented only by hard chert, and the main lime of the same district before it thins out and dies away becomes remarkably cherty, both by the change of whole beds and the introduction of chert nodules. There appears some reason to attribute this effect, in one case, to the operation of a vein, while in others it may, perhaps, be properly viewed as indicating merely the suppression of the calcareous deposit independently of the silicious. It must be owned, however, that the notion of miners, and that first suggested to the Geologist, agree in assigning the

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effect in some instances, even independent of dykes or veins, to a real chemical conversion of the nature of the rock since its deposition.

therefore employed in certain parts of the iron furnaces.

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### Millstone Grit Series.

Mineral  
composition.

The difference of composition between the coarse sandstones which abound in this part of the series, and those of finer grain which alternate with the limestones below and the coals above, is rather apparent than essential. That all these sandstones are composed of the broken and triturated ingredients of older crystalline, generally granitic compounds, is evident upon inspection. Their most abundant ingredient, sand, is plainly in the state of minute pebbles, and the size of these grains is sometimes so very small, that their coherent mass assumes almost a crystalline aspect, as, for example, in the Calliard stones. On the other hand, in millstone grit they are of all sizes under an egg, though pieces of greater size than this are sometimes seen. These are evidently quartz pebbles of different kinds, corresponding to the quartz of veins and of granites. Rose quartz also has been observed. The next abundant ingredient is felspar, which is probably present in all these sandstones. In the millstone grit this mineral occurs in rounded pebbles whose internal structure is perfectly crystalline, like the large rhomboidal crystals in the porphyritic granites. Hence we learn clearly the history of such a sandstone deposit. The materials were derived from crystallized rocks, and were subsequently more or less rolled about and deposited in water. Mica, the third ingredient of granitic rocks, is less abundant in millstone grit, except in certain layers where it is occasionally very plentiful. It is usually of a pale silvery colour and is in very thin fragmentary scales. The decomposition of the felspar leaves a white, soft, unctuous substance, analogous to the kaolin of decomposed granite, and this forms a feeble cement for the grains of sand and mica. Occasionally in millstone grit, as in the other sandstones of the carboniferous system, we find oxidulous iron, and some other mineral substances not easily recognised, and in Lancashire, frequently, fragments of shale, coal, &c. Every thing, therefore, concurs to prove the mechanical watery origin of millstone grit, and by consequence of all the other sandstones associated with it, the differences between them being only of degree. In the same manner nearly a gradual series of changes assimilates sandstone and shale, and it is sufficiently proved that the only really chemical aqueous deposit of this whole system is the limestone.

The millstone grit of the Southern coal fields is usually a much harder and more compact and cherty rock than the coarse pebbly strata which bear this name in the North of England. Finally, we must repeat the remark previously made that this series is limited in extent, not being of much importance or really characteristic of a certain period except between the Trent and the Tyne. Through the remainder of Northumberland it is less remarkable than several other equally coarse grit rocks, called *crag grits*, in Mr. Smith's Map of Northumberland, which lie in the limestone series considerably below the upper limestone belt. Excellent building stone is furnished by this rock in Yorkshire, Lancashire, and Derbyshire, and by its representative, the "Farewell Rock" of Dean Forest and South Wales, which have the valuable property of standing great heat, and are

### THE COAL FORMATION (OR COAL MEASURES)

consists of alternating strata of sandstone, shale, and coal, with courses of nodular ironstone, layers of bivalve shells, and, in a certain part, argillo-calcareous balls and nodules generally enclosing ammonites, pectens, &c.

None of these strata differ individually in any essential points from the analogous deposits in the millstone grit, or limestone series beneath; their characteristic features are derived from their combination. It is, indeed, generally true, that the sandstones of the coal measures are softer and more argillaceous than those of the series below, that the coal shales are less indurated and less fissile than the "plates" of the limestone group, and the coal generally of better quality. But it is by the greater abundance of the coal seams, and by the absence of limestone beds that the upper part of the carboniferous system is to be distinguished from the lower. It is, therefore, perfectly conceivable, that cases may occur when the lower or calcareo-carboniferous group may, by the attenuation of its limestones and the thickening of its coals, become so similar to the upper group or true coal measures, that their relative ages can be only determined by collateral evidence. This extreme case has, indeed, hardly yet been observed in any of the known coal districts of the New or Old World, but the approach to it in Northumberland and Scotland are sufficient to show that the coal measures have no other real difference from the lower parts of the carboniferous system, than the total absence of the oceanic deposit of limestone. In many coal fields the reason of this difference is easily determined by the abundance of *fresh-water shells*, beds of shale, and ironstone, alternating with the coal.

We have seen with what certainty the range of the mountain limestone can be followed through Great Britain, and its detached portions referred to their true place in the series of its beds, and thus Geological parallels be established between the Mendip Hills, Derbyshire, Yorkshire, and Northumberland. The coal measures of Great Britain cover quite as large a surface, and are, perhaps, quite as well identified *in mass*; but the details of the several coal fields are too discordant, to permit many of these parallels to be drawn, without which the *method of variation* by which one such coal field becomes different from another cannot be determined. This is so entirely well known, that often in the same coal field the differences are so considerable as to render it difficult to identify the beds of the two extremes. It must be owned, however, that this is partly owing to the confusion of nomenclature amongst the workmen, though principally to the sudden changes of chemical quality to which the coal seams are liable.

The extent of the coal fields of England and Wales may be seen upon Mr. Smith's and Mr. Greenough's Geological Maps; those of Scotland also are sketched upon Mr. Smith's Map; Mr. Griffith's Surveys and Mr. Weaver's observations have contributed much information on the coal measures of Ireland, and many valuable notices in the *Annales des Mines, Annales des Sciences Naturelles*, &c., make us acquainted with the same series in France. For the Netherlands the same Journals and the Memoirs of Omalius d'Halloy, and for the German and Transylvanian coal fields the works of

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Villefosse, Freisleben, Hoffman, Sternberg, and others may be consulted. Mr. Conybeare has given a general view of these foreign coal tracts in the Geology of England and Wales.

English  
coal fields.

We shall consider the characters of the principal English coal fields in the following order:

1. The great Northern coal fields of Northumberland and Durham, Yorkshire and Derbyshire, and their appendages.
2. The South-Western coal fields of South Wales, Dean Forest, Somersetshire, and Kingswood.
3. The coal fields of North Wales and Shropshire.
4. The central English coal fields.

That the great Northern coal fields of Northumberland and Durham, and of Yorkshire and Derbyshire, were formed under very similar circumstances, and, if never connected towards the borders, were united in the deeper parts of the deposit, will appear from the following comparisons. The Northern and Southern portion of this great tract, though now separated sixty miles, agree in being formed within a belt of coarse pebbly sandstones (millstone grit) associated with thin coals, which overlay the mountain limestone, and in being covered *unconformably* by the magnesian limestone. Coals of like quality are worked in these coal fields in the same parts of the series, bituminous coals of excellent quality in the lower part, quick burning coals in the upper part. Ironstone courses are most plentiful in the middle and lower part, where also lie the "muscle bands," of which regular layers have been some time known in the coal field of Yorkshire, and are not without representation in that of Newcastle. This latter analogy is very remarkable, and the occurrence of these muscle bands is almost a peculiar character of the great Northern coal fields.

A comparison of the details of these coal fields would afford an excellent test of the points of analogy, and the extent of variation, which may be expected to occur in neighbouring carboniferous deposits.

The broadest part of the whole tract is between Halifax and Ferrybridge, or rather Went Bridge, in Yorkshire, where the dip is moderate and regularly to the South-East, the stratification not subject to more than usual disturbance, and the greater part of the coal seams worked to supply the wide-spreading industry of the West Riding. The whole coal system of the Country is thus unfolded, all its products are employed, and the ranges of most of the beds perfectly known. In addition it happens fortunately, that not only the millstone grit is remarkably distinct, and the series immediately above it, the lowest part of "the coal field," unusually developed, and rich in organic remains, both animal and vegetable, but the uppermost part of the system beneath the magnesian limestone is also fully exhibited. This is therefore on all accounts the most complete coal field in the Island, and the fittest to serve as a type of comparison for the others.

Yorkshire  
coal field.

The following mode of classification of the Yorkshire coal seams will be found very natural and convenient, for the several groups of coals here assumed have certain collective characters derived from this combination, and occupy distinguishable ranges of mostly argillaceous country between lines of sandstone hills.

Magnesian limestone unconformably covers the coal seams.

Upper coals ... { Shales and Badsworth coal.  
Ackworth rock.

Red rock of Woolley, Hooton—Roberts, &c

Middle coals	{	Furnace coals.	Barnsley thick coal.
		Intermediate coals.	Rock of Horbury. Middle coals.
		Ironstone coals.	Silketone beds. Low Mow and Flockton coals.

Flagstone rock of Woodhouse, Bradford, Elland, Penistone, &c.

Lower coals.	{	Shales and ganister stone.
		Coals.
		Shales and ganister stone.
		Coal. Shales, &c.

Millstone grit lies below the "coal series."

The lowest portion of the Yorkshire coal strata resting upon the millstone grit produces comparatively but a small quantity of coal, and this not in general of a good quality. But no part of the coal field is more curious in its Geological relations, or more worthy of close study by those who desire to penetrate into the history of the production of coal. We may define this lowest coal series very simply by saying, that it is included between the millstone grit beneath and the flagstone rock above, having a thickness of about 120 or 150 yards, and enclosing near the bottom two thin seams of coal, one or both of them workable, and several other layers scattered through its mass too thin to be worth working.

The most regular and continuous of all these coal seams, reaches in a few places the thickness of 27 or 30 inches, but is generally only about 16 inches, and is worked at Yeadon, Rawdon, and Horsforth, near Leeds; at Baildon and Heaton, near Bradford; at Catharine Slack and Swan Banks, near Halifax; at Bull Houses, near Penistone; and at several points West of Sheffield. It would have been impossible to have traced so thin a seam of coal along so extensive a range without some peculiar facilities, some points of reference more distinct than the varying quality of the coal, and the still more irregular fluctuations of the sandstones and shales. This coal seam is covered by a "roof" unlike that of any other coal bed above the mountain limestone in the British Islands; for instead of containing only the remains of plants or fresh-water shells, it is filled with a considerable diversity of *marine shells* belonging to the genera *pecten* and *ammonites*, and in one locality specimens of *orthoceras*, *Posidonia* and scaly fishes have been obtained from certain nodular concretions, called "baum pots," lying in it. The uniform occurrence of these pectens and ammonites, through so wide a range, over one particular thin bed of coal, and in no other part of the coal strata, is one of the most curious phenomena yet observed concerning the distribution of organic remains, and will undoubtedly be found of the highest importance in all inferences concerning the circumstances which attended the production of coal.

In this part of the coal system we may observe, besides the very remarkable layer of marine shells, several occurrences of a peculiarly hard silicious sandstone, called galliard, ganister, seatstone, &c, which, in fact, is the same thing as the crowstone of the mountain limestone series in Swaledale. This stone in some cases forms the floor or sill of the coal, a circumstance never observed in the upper coal strata, amongst which, indeed, galliard never occurs in its true character. Hence this whole group of strata may be appropriately termed the

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Lower or  
ganister  
coal series.

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The ammonites and pectens which lie above one of the seams of coal, and still more the orthocera which sometimes accompany them, are remarkably analogous, and perhaps in part identical with fossils of the mountain limestone. The galliard is likewise to be compared with similar stones in the mountain limestone series, and therefore the ganister coal series might be with much propriety associated with the upper mountain limestone series of the Penine chain, or with the millstone grit series of Derbyshire, and thus the flagstone would appear to be the lower limit of the true coal measures. But an examination of the neighbourhood of Halifax has shown another order of phenomena and another set of shells, which connect this same series with the upper or true coal measures. In the upper coal series of Northumberland, Derbyshire, and Yorkshire, are several layers of bivalve shells, commonly referred to the genus *unio*, from which the fresh-water origin of these coal deposits has been inferred. In the midst of this series of ganister coals two layers of these shells occur, one of them about the middle of the series, considerably above the *pecten* coal, the other near the bottom, and considerably below that coal.

No shells of this kind have ever been met with in the mountain limestone group which there is every reason to consider as of decidedly marine origin; not one of all the zoophytic, testaceous, or crustaceous reliquiae of this limestone has ever been found in the upper coal series. This opposition of zoological characters would appear to be fully explained if the coal deposits were admitted to have been accumulated in fresh water. And this opinion is perhaps generally adopted.

We find then in the lowest coal series, which is placed on the line of transition between the marine and fresh-water deposits, zoological and mineralogical characters common to both. Examined in detail we find these characters not mixed, but alternating in such a manner as if there had been one periodical return of the marine element into its ancient receptacle, after that had been for some time occupied by fresh water and its few inhabitants. The effects of this irruption having as it were worn out, the zoological characters of fresh-water deposits are again manifested at intervals, in the upper system of coal beds, till this series is finally ended, and marine exuviae reappear in the magnesian limestone.

If, from whatever cause, we could witness the effects of a general irruption of sea-water into a modern lake of great extent and considerable depth, it is probable that the resulting phenomenon would be perfectly analogous in kind to those described above. But this irruption of the ancient ocean into the coal basin of Yorkshire, was probably not produced by any violent convulsion in that basin, (for there is no unconformity between the supposed fresh-water and supposed marine deposits,) but by some disturbing causes originating at a distance. As the elevation of the Western Alps has probably occasioned the dispersion of boulders in Dauphiné and Provence, and the uplifting of the Scandinavian Alps has been followed by diluvial currents in Germany without much affecting the position of the strata in those Countries, so may the Yorkshire coal district have felt the transient shock of some distant convulsion. The periodical revolution in the nature of the waters which operated the deposition of the lowest coal strata in Yorkshire, bears so remarkable an analogy to some of the phenomena of the marine-lacustrine tertiary deposits,

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that the same principles will probably serve as a basis for the explanation of both cases.

In both cases we have a *decidedly marine* deposit below, and a *decidedly fresh-water* deposit above; the intermediate ground is not exactly neutral, but sometimes shows gradations from one to the other, and sometimes periodical alternations, accompanied however by so entire a parallelism of strata, that in seeking for the cause of these changes, we are compelled to have recourse to agency at a distance, to the blocking up of the outlet of an estuary, or to irruptions of the sea, arising from subterranean disturbances in a different quarter.

The lower coal series of Yorkshire is terminated above by a thick deposit of sandstone, which is never so coarse as the millstone grit, and generally appears to be more argillaceous. Its degree of consolidation varies according to localities and circumstances of drainage, but there is hardly a single point in its whole range, from the vicinity of Leeds to beyond Sheffield, where the title of flagstone rock is not eminently applicable to it. Along this whole range, by the valley of the Aire to Bradford, over the hills to Halifax and Elland on the Calder, and by Huddersfield and Peniston to Sheffield, it is the grand repository from which the immense demand for Yorkshire flagstone, both within the County and for all the Eastern and Southern coasts, is supplied. In particular situations, especially near the surface, it is often so thinly laminated as to produce good roofing slate, while the deeper parts of the quarries produce capital building stone. This diversity of qualities is consistent with great simplicity in structure. It is a finely laminated stone, having its beds in general very parallel, and thus, according as the whole mass of a bed is employed, or as it is split into portions or resolved into its component plates by the action of natural causes, wallstone, flagstone, and slate result. The micaceous surfaces of every common flagstone immediately disclose to us the cause of its natural partings; and further examination shows the whole thickness to be divided by other layers of mica into a number of parallel plates, which sometimes separate by the mere influence of the air, but generally, after being once dried, cohere together with considerable force. In this case it is difficult to say what technical use should be made of the term *strata*, which may with equal verbal accuracy be applied to the micaceous laminae, or the plates of slate or flagstone to the beds of the rock singly, or the whole united mass of sandstone layers. In Mr. Smith's nomenclature the whole flagstone rock is one stratum. However this may be determined, there can be no doubt that even the least and thinnest of the micaceous layers owes its origin to a particular operation of water, and required the intervention of a certain interval of time, to permit the separation of the grains of sand and the scales of mica.

It has been said above that the micaceous laminae, plates of flagstone and beds of the rock, were all parallel. This is usually and very exactly the case, but in certain places while the beds and flagstones, which are only *lesser beds*, are parallel to one another, the micaceous layers which make up the mass of the beds, form considerable angles with the plane of their surfaces.

Thus in plate i fig. 2 the upper part of the diagram shows all the partings parallel; and this is the ordinary case of the flagstone rock, but in the lower part of the diagram the micaceous laminae are inclined to the other surfaces of parting.

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Such flagstones have generally a rough or ragged surface, and are much liable to scale off in irregular "shells," which disfigure the beauty of the stone. This oblique lamination of the mica strongly reminds us of the "false bedding" of millstone grit, and of the shelly beds of oolite, which probably were formed in slightly agitated water.

The surface of the rougher flagstone beds is also liable to other peculiarities, as waves or undulations, like the ripple marks on a sandy shore, little hard knobs on one face corresponding to depressions on another, and sometimes a vermicular marking, which more than any thing else resembles the arrangement which semi-fluid matter assumes on smooth surfaces of stone, when these, after having been laid together, are forcibly pulled asunder.

The micaceous layers are not unfrequently coloured with a mixture of carbonaceous particles.

Vegetable remains lie in this rock in many places, and in considerable plenty. Equisetaceous plants in particular are abundant in it about Leeds, accompanied by trihedral fruits. *Lepidodendra*, *sigillaria*, &c. occur in it less plentifully.

In general, what is said of the accidents of structure of the flagstone rock of the Yorkshire coal fields applies to the laminated sandstone rocks of the mountain limestone, and even to the analogous but more recent layers in the oolitic coal system on the coast of Yorkshire.

Middle coal  
series.

This is the most valuable part of the Yorkshire coal field, and includes as many as ten workable seams of coal, of various quality, with several layers of ironstone bands, one of them full of fresh-water shells. The flagstone rocks define the series below, and the coarse, often iron-stained sandstones of Newmiller Dam, Woolley Edge, and Rawmarsh form its upper boundary.

It may be convenient to divide this great group into three portions, thus:—

- Red rock of Woolley Edge.
- Furnace coals of Barnsley, &c., including the eight or ten feet seam.
- Rock of Horbury and Wentworth House.
- Swift-burning coals of Middleton, Dewsbury, &c., with bands of "muscles."
- Bituminous coals of Silkstone, Low Moor, and Flockton.
- Flagstone rocks beneath.

Upon the coarse rocks of Woolley Edge lies the upper series of coal measures in Yorkshire, which exhibits alternations of sandstones and shales very much like those of the middle and lower groups, but without the layers of muscles, and generally without the presence of productive ironstone bands. The reliques of plants are more rare in these strata, and the coal is of inferior quality, more earthy and less bituminous. Two considerable seams of coal near the bottom, worked at Wragby, Sharleston, &c., and one or two thinner seams nearer the top of this series, appear to be the last of the formation, and are unconformably covered, as are all the others in their turn, by the magnesian limestone, against which deposit the line of separation is hard and distinct.

Compari-  
sons with  
other coal  
fields.

We are now in a condition to institute a comparison between the results of observation on the strata of the Yorkshire coal fields, and those which had been drawn from similar researches on the other coal districts of Britain and the Continent. For this purpose it will be of little use to take into account the number or thickness, or chemical quality of the beds of coal, since these

characters, however important locally, are too variable to guide us across even the whole extent of a single coal basin, and vanish altogether upon distant points. We must, therefore, restrict ourselves to the most general divisions of the carboniferous series, and compare the coal fields with reference to the strata which separate the coal from the mountain limestone beneath, the occurrence of bands of ironstone and muscle-shells, the nature of the rocks and shales, and the distribution of organic remains.

The characters of the Yorkshire coal fields are recognised in their continuation Southward through Derbyshire and Nottinghamshire. The same ranges of millstone grit and shales lie beneath; similar rocks of hard ganister lie in the lower part, with a similar belt of useful flagstone. The lower part of the series contains the most bituminous coals, and the most abundant course of ironstone, some of which contain fresh-water shells, and the upper parts yield similar swift-burning thick coals.

The Lancashire and Cheshire coal fields are certainly portions of this great Northern system, separated in consequence of the subsequent uplifting of the mountain range of the Penine Alps. The same ganister and flagstone occurs near Stayley Bridge, resting in the same order of succession upon the same millstone grits, and though the broken condition of the coal fields on the West of the summit ridge scarcely allows of the same accurate delineation of the courses of the coal beds, enough is already known to justify the reunion of the coal-deposits on both sides of the Penine Alps.

Notwithstanding the great interval in the superficial range of the coal strata between Aberford and Cockfield Fell, the series in the Durham and Newcastle coal fields is very analogous to that of Yorkshire.

But hitherto, no layer of marine shells has been noticed in the lower part of the Newcastle coal fields, and, therefore, the inference of alternate inundations of the sea and fresh water cannot be applied to this coal field, though the general conclusion of marine deposits below, and freshwater deposits above, remains unimpaired.

Fresh-water shells, accompanied by nodular ironstones, and numerous reliques of equisetiform and filicoid plants occur *without limestone* beds in the coal fields of Clackmannanshire, Falkirk, and St. Andrew's, but most of the Scotch coal fields, like that of the North and West of Northumberland, are formed by a development of the carboniferous limestone group of Yorkshire and Durham, and contain marine shells.

The immense coal basin of South Wales (which is, in fact, as Mr. Conybeare has shown, divided into two parallel basins by a longitudinal axis of elevation,) presents so many features in common with the detached coal tracts of Dean Forest, Kingswood, and the valleys of Somersetshire, that for our present purpose we may conveniently group them together.

The total thickness of the coal strata is very great, for in the deepest part of the basin near Neath, the lowest strata of coal are nearly 700 fathoms below the outcrop of some of the superior strata in the more hilly parts of this district. There are (according to Mr. Martin) 23 beds of workable coal, making altogether 95 feet, 12 of them from 3 to 9 feet thick, 11 from 16 inches to 3 feet; besides numerous other beds from 6 to 18 inches thick.

The coal on the North-Eastern side of the basin is of a coking quality, excellent for the iron manufacture; on the North-Western it contains little or no bitumen,

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Ch. II.The great  
Northern  
coal fieldsGreat  
South  
Wales coal  
field.

**Geology.** being what is called stone coal or culm; on the South side, from Flintshire to Carmarthen Bay, it is of a bituminous or binding quality. The cause of these extreme differences in the quality of the coal is not known, and, indeed, the subject of the varying quality of a coal bed has never yet been adequately investigated. Many analogous though less striking examples are familiar to every coal-worker of sufficient observation and experience.

The numerous excavations along the Northern border of the South Wales coal district, for the purposes of the iron manufacture, present us with a complete section of the middle and lower parts of the coal measures, the limestone series beneath, and the general base of old red sandstone.

The lowest part of the coal measures consists of alternations of sandstone and shale, without coal, the lowest bed (in the place of millstone grit) being a conglomerate sandstone. Above this series, two or three thin seams of coal occur, and these are followed by an argillaceous series, containing many thick and valuable beds of coal, and sixteen layers of ironstone in thin beds and nodules. Whether the ironstone nodules contain shells has not (it is believed) been stated, but the general analogy of arrangement of the coals and ironstones to that which has been described in the Northern coal fields, will be immediately obvious.

It appears that the upper part of the coal strata is characterised by the predominance of coarse sandstone with carbonaceous specks, like that called Penant in Somersetshire, and that a considerable thickness of such rocks intervenes between the upper and lower coal seams.

This sandstone is occasionally highly micaceous and fissile, and yields very good flagstone and even roofing slate.

The coal strata of this entirely insulated coal field rest occasionally upon a coarse sandstone like millstone grit, but the general floor is mountain limestone, which contains a layer of oxide of iron, in such plenty as to feed the iron furnaces. The coal seams, seventeen in number, contain about thirty seven feet in thickness of clear coal, which is mostly bituminous and swift-burning, but in the lower seams partakes more of a coking quality. The ironstone nodules which lie in the shales are of little importance; the sandstones are mostly in the lower part of the section.

The neighbouring coal field of Nevent rests on transition strata along the Southern and Western edges, and on old red sandstone along the North-Western. (*Geological Proceedings, 1833*)

The broken coal deposits of South Gloucestershire and Somersetshire agree in being begirt by an irregular belt of mountain limestone and old red sandstone, and occasional patches of sandstones occupying the place of millstone grit. The irregular undulations of the strata in this district, and their concealment through extensive tracts by overlying deposits, present formidable obstacles to the attempt to trace the series of beds which constitute this coal field.

Mr. Conybeare supposes that it may contain as many as fifty or sixty coal seams, most of them very thin, hardly any of them exceeding one yard, and, therefore, unless of good quality, in a country at some distance from more productive collections, and aided by the improvement of modern machinery, scarcely capable of being worked to profit.

As in the South Wales coal field, the system is in the lower, and the Penant grit rock is the middle part of the series: the shale beds frequently contain beautiful impressions of ferns and minute shells. (*Geology of England and Wales*.)

The Somersetshire coal fields have been admirably illustrated by Dr. Buckland and the Rev. Wm. Conybeare (*Geological Transactions*.)

The well-connected coal basin of Flintshire, on the basis of which the estuary of the Dee is formed, extends from North to South somewhat more than 30 miles, from Llanassa to near Oswestry in Shropshire, forming an exterior belt coextensive with the range of the mountain limestone from the North of the Clwyd; where that limestone is partially interrupted by the mountain of Selattyn, the coal shales rest immediately on the transition slate of that mountain. The coal strata dip generally Eastward, and form in the Northern part a trough beneath the estuary of the Dee, and rise again on the Eastern side of that estuary in the district called Wirral, from whence, sinking again beneath the red sandstone, along the course of the Mersey, they may possibly be prolonged to the South Lancashire coal beds, near Prescott.

This coal basin in Flintshire commences with beds of shale and sandstone, answering in position and character to the shale and millstone grit of Derbyshire. The coal is of various thickness from three-quarters to five yards, and consists of the common canal and peacock varieties. (*Geology of England and Wales*.)

The broken patches of coal strata which lie on the South of the Vale of Severn near Shrewsbury, are arranged according to the irregular positions of the transition rocks, which in the Stiperstones, Longmynd, Wenlock Edge, the Wrekin, Caer Caradoc, &c, extend themselves in a curve far to the East of the great body of the slate rocks. The true relations of the coal strata to the transition ranges, between whose projections they are enclosed, have recently been examined by Mr. Murchison, and connected with general views of the dislocations along the line of the upper slate formations. It appears that the carboniferous strata repose on the edges of the slates, and dip towards a common centre under the new red sandstone. At Pitchford the whole carboniferous series is represented by a bituminous breccia, of a few feet in thickness. Three thin beds of coal are, for the most part, observable, and the deposit is distinguished by an included band of limestone similar in mineral aspect to the lacustrine limestones of Central France, and containing minute planorbis very similar to those mentioned above from the middle coal seams of Yorkshire and Northumberland. (*Geological Proceedings, 1833*.)

On the East side of the transition ranges of the Coalbrook Dale. Wrekin and Wenlock Edge lies the coal field of Coalbrook Dale, which contains at the bottom a sandstone called the little flint, at which the lower part abounds in pebbles, and is in fact a millstone grit. The ironstones, which lie in five or six layers, are balls or broad flat masses, like those in Yorkshire, &c, and contain abundance of the same vegetable impressions, and a few shells; those which we have examined (belonging to the marine genera orbicula, conularia, ammonites) indicate the propriety of an inquiry into the distribution of the carboniferous remains for comparison with the results of this investigation in Yorkshire.

The coal beds are mostly thin; the iron stones

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are too sulphureous for other uses than lime-burning, and are called stinkers; twelve beds of good coal, in all twenty-five feet thick, the thickest being five feet, succeed, and the lowest bed of the whole formation, eight inches thick, is sulphureous. The best coal of this coal field usually presents a mixture of slate coal and pitch coal, rarely of cannel coal; none of it possesses the property of coking.

The sandstones of this coal tract are usually fine-grained and micaceous, and speckled with fragments of coal; but some of them are coarse-grained, and two remarkably so. The sandstones generally contain vegetable impressions, but never form the roof of the coal, which is invariably shale. Two beds of coarse sandstone, fifteen and a half feet in thickness, are entirely penetrated by petroleum, which flows out perpetually in the *tar spring* at Coalport. This bitumen is likewise found in the basses or indurated slate clay. These details are chiefly derived from observations at Madely colliery, where a pit, sunk to the depth of 729 feet, passes through all the strata, eighty-six in number, which constitute the coal formation.

This coal field rests at Stacerway, and near Little Wenlock, on a thin band of limestone, which Mr. Murchison has recently proved by its fossils to be mountain limestone, whilst in the contiguous extension of this field, the carboniferous strata overlie, *unconformably*, various members of the transition series, with one of which, the transition limestone of Wenlock Edge, they are brought into *conformable* apposition at Lincoln hill.

Clee Hills,  
&c.

The divided coal-basin of the Clee Hills is elevated upon the mountain limestone and old red sandstone of Corvedale, and contains several seams of coal and layers of ironstone, much confused in their arrangement by interpositions of basaltic dykes and overlying masses, and resting below on a hard conglomerate sandstone. This interesting country has been recently examined by Mr. Murchison. On three sides of the Brown Clee Hill, the coal strata rest on old red sandstone, which to the West is a coarse conglomerate; but on the fourth or South-Eastern side, there is interposed between the old red and the lower coal grits, a thin zone of mountain limestone. (*Geological Proceedings*, 1833.)

Trap rocks confuse the arrangement of the coal strata in the whole space between Corvedale and the Severn, which includes the narrow coal field of Billingsley and Burdley, which has also attracted the labours of the same Geologist.

Central  
coal fields.

The double coal field which surrounds Asby de la Zouch is based on mountain limestone, which, like some portions of that of Derbyshire, contains abundance of magnesia; there is, however, no particular correspondence to be remarked in other respects; no millstone grit has been recognised, no flagstone, nor conchiferous ironstone. Amongst the seams of coal is one of the variety called cannel, and another from seventeen to twenty-one feet in thickness. (*Geology of England and Wales*.)

The strata of the Warwickshire coal field are based upon a compact cherty sandstone, called by Mr. Conybeare "millstone grit," but no limestone appears round the escarpment of this narrow coal tract. The seams of coal are liable to great changes of thickness in consequence of the occasional attenuation of the interposed strata of shales.

The coal field of Dudley, Bilston, and Cannock Chase

agrees in part with that of Coalbrook Dale, but differs from all the others by the character of the subjacent limestone, for this is generally admitted to belong to the transition system. The coal measures are supposed by modern writers to be unconformed to the limestone, but their dips correspond in direction though not in degree. The limestone is uplifted into a saddle-shaped or anticlinal ridge; the coal strata rest upon its slopes, and are covered by the new red sandstone formation.

There is no millstone grit, nor any flagstone, and (as usually among the central coal basins) the strata are mostly argillaceous. Ironstone courses occur in several parts of the series, but the only valuable ones are near the bottom. The seams of coal are numerous, but only the lower ones are workable. They are of various thicknesses from two to ten yards, or even fifteen yards.

It is not, however, to be supposed that these enormously thick seams are single beds of coal; they are in fact composed of several beds locally accumulated together, with certain partings, which in other places swell out into considerable thicknesses of shale. Thus the upper part of the ten-yard coal separates from the rest of the beds, and under the title of the "flying reed," becomes a totally distinct bed in the Northern part of the coal tract.

The coal fields of Ireland occupy very large tracts in the centre of that country, and are upon the whole very analogous in general mineral characters and organic contents to those of England. The same absence of limestone, the same kind of succession of sandstones and shales is remarked in them. Carbonaceous or stone coal, like that of South Wales, abounds in the Leinster and Munster districts; bituminous coal in Connaught and Ulster. The Munster coal district is stated by Mr. Griffith to be of greater extent than any English coal field. In this tract (County of Cork) Mr. Weaver supposes certain anthracitic beds to be interposed in greywacke, and to be subject to all its flexures, but certainly the greater part of the coals of Cork and Limerick are of the same age as the English coals. At Ballycastle the coal is found in connection with basalt. (See Conybeare, *Geology of England and Wales*.)

Ireland.

#### *General View of Circumstances under which the Coal Beds were deposited.*

1. Few subjects in Geology have been examined under more various points of view than the question of the origin of coal, and the circumstances under which it was deposited. We may wonder at the philosophical blindness which would permit in the last century protracted disputes concerning the vegetable origin of coal, when so many thousand plants converted it to that substance were found in the shales and sandstones of every coal district. But in those days this kind of evidence was so little understood, that the inimitable impressions of ferns and other plants from which we are now accustomed to reason concerning the climate and other conditions of the ancient world, were not even admitted to be reliques of the vegetable kingdom.

There is no necessity to enlarge upon the proofs of the origin of coal from vegetables, drawn from an examination of its chemical constitution as compared with vegetable products, and the composition of the ligneous parts of plants, and from the unanswerable identity of the carbonaceous substance, into which a vast multitude of



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fossil plants have been converted. The chemical constitution of this carbonaceous product of the individual vegetables, is exactly analogous to the chemical constitution of coal; and it is quite probable that hereafter the reason of the variations to which both are subject, whether dependent on the original nature of the plant or produced by subsequent operations, will be as apparent as that of the general agreement arising from a common vegetable origin. (For some remarks on a part of this subject see ch. i. p. 547.)

II. Admitting then the vegetable origin of coal, the next question relates to the situation where the plants grew from which the vast mass of the coal seams was derived.

Many of the plants accompanying coal are of unknown types, and some are too imperfect to permit any botanical deductions; but the researches of Naturalists have nevertheless been successful in determining some general characters of this ancient flora.

The greater number of these plants were decidedly terrestrial.

They appear to be most analogous to tropical tribes of vascular, cryptogamic, and coniferous plants.

They grew then on the land, and it is probable from M. Brongniart's researches, that this land was in a high degree subject to heat and moisture, more so than perhaps even the coasts and islands of tropical seas, to the flora of which situations the coal plants present most remarkable general approximations. (See p. 603.)

III. We may now venture upon the main part of the inquiry which relates to the origin of coal, *viz.* whether the plants from which coal was produced *grew in their present situations*, and were there submerged and buried beneath marine or fluviatile deposits, or were swept down to their present repositories *from distant situations* by land floods and other causes. To guide us in this inquiry the following data may be premised:

1. The *generally uniform, or gradually varying*, thickness of the several coal seams over a very large area.

2. The broken and fragmentary condition and confused intermixture of the plants which accompany coal strata, and their being *generally without roots*.

3. The occurrence of the *same species* of plants in shales, ironstones, and sandstones.

4. The occasional vertical position of *broken stems* of large trees.

5. The *parallelism or conformity* of the several beds of coal.

6. The extreme differences in the thickness of the several seams, and the occurrence of many *very thin plates of coal* through many of the coal shales.

De Luc and several eminent Geologists, and lately M. Adolphe Brongniart, have supposed coal beds to have been originally a sort of peat bogs, or masses of vegetable reliques accumulated round the place of their growth, upon which other vegetables grew, and that subsequently these tracts of country during some extensive convulsions subsided below their former level, and were covered by various mechanical deposits. This hypothesis seems to have been suggested by the seeming analogy in some respects between the chemical changes which have happened to the vegetable matter of peat bogs and of coal, by the occurrence of stems of plants vertically in the coal strata, and by the supposed difficulty of otherwise explaining the acknowledged regularity of the coal beds.

These circumstances may appear to favour the hypothesis of De Luc, but they cannot make us overlook very serious objections to it.

The formation of *peat bogs* is, as far as we know, not of the kind here supposed. It is not by fragments of trees and herbaceous plants accumulated round the place of their growth, but of a variety of successively dying mosses and other moisture-loving plants that the peat bogs *grow up* to the extent which they occupy on the high cold hills of the North of England.

There is, however, another kind of vegetable accumulation which may be thought to throw more light on the origin of coal. The *turf or peat moors*, as they are called in the North of England, which occur in low ground toward the estuaries of rivers, and along the margin of the sea, in many parts of England, contain a mass of vegetable matter, composed of mosses and other humid plants, roots of liag, &c. and envelope trunks of trees, sometimes prostrated in particular directions, apparently cut by art or decayed by time. In some places are oak, in others birch or fir, according, as Mr. William Smith has observed, to the nature of the soil below, which is sand, marl, or clay. With them often lie the remains of terrestrial quadrupeds, land shells, &c.

The marls sometimes contain fresh-water shells, but never marine exuvie. In most places these accumulations of vegetable reliques are below the level of the sea, and covered by various alternations of mechanical deposits, sands, and clays brought down by the rivers or deposited by the tide.

These phenomena appear to admit of an easy explanation, if we allow that the relative level of the sea and land has been locally subject to variation, and thus the drainage of the country deranged.

The greatest part of the vegetable mass grew in its present situation, it was a humid forest where the leaves and branches of the trees, mingling with the herbaceous covering at their base, formed an extensive carbonaceous mass, which enveloped the trees when they fell by any great violence of wind or flood, perished by natural decay near the base, or yielded to the axe of the old inhabitant. In cases where the situation was elevated, or otherwise removed from the action of the tide, the ancient forest has been sometimes converted to a lake, or overwhelmed with the ruins brought by a land-flood. Along the side of great rivers, where the level was permanently below the floods or tides, many successions of sandy and argillaceous deposits have taken place, and sometimes a second accumulation of vegetables; and thus the whole alluvial *sediment and subterranean forest* resembles in some important respects the alternations of earthy deposits and carbonaceous layers which compose the ancient coal strata.

We have, however, not yet exhausted the heads of the Lake subject of the agglomeration of vegetable reliques. In many situations in England, as in Holderness, (*Geology of Yorkshire*;) they have been swept down from the land, and accumulated on the beds of lakes in a pretty regular stratum of partly decomposed leaves and herbs, with branches of hazel bushes, nuts, &c. and fragments of larger trees. Over them the lake has since diffused, in regular layers, the sediment brought into it by the streams and floods, with the shells which lived in the waters.

The Mississippi and other great rivers of the World whose banks are clothed with immense primeval forests,

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Subterranean forests.

Peat bogs.



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where from age to age the trees as they fall are rolled away by the periodical inundations, deposit in their wide mouths alternate and repeated layers of vegetable and earthy matter, and thus present us with another analogy to the coal strata more exact in detail than any of the preceding, and more justly comparable in extent of effect.

To what distance in the sea trees may be rolled by the mighty continental floods, those who have been accustomed only to contemplate the trifling streams of England, can have no proper idea; but the navigator who at the distance of two or three hundred miles recognises in the Atlantic the last effort of the current of the Amazons, or in the Bay of Bengal observes the immense accumulations of earthy sediment transported by the gentler waters of the Ganges, will readily admit that the estuary deposits from such rivers may exceed the area of the most extensive of our coal basins. (See Isyell's *Geology*.)

Effects of  
higher tem-  
perature.

If we are right in the inference that the ancient flora which lies buried in our coal tracts was the growth of even more than tropical heat and moisture, we may readily conceive how these circumstances, joined to the certain fact that the land was then of far more limited surface, would also explain the greater amount of both the organic and inorganic depositions from the ancient drainage of the earth. For a higher temperature of the air and earth, accompanied by more abundant moisture, would naturally be followed by more luxuriant vegetation, more abundant precipitation of rain, greater and stronger rivers, and more violently excited floods. As the rich vegetation and atmospheric storms and destructive floods of the tropical region exceed those of our colder latitudes, so would the effects of the ancient floods in still hotter climates surpass the most powerful results of the present combination of agents.

It is possible that the effect may have been heightened by some essential difference in the constitution of the atmosphere; (M. Brongniart supposes by a large proportion of carbonic acid;) but without at present entering these fields of hypothesis, the botanic characters of the fossil flora appear to warrant the conclusion above stated.

From this short review of the operations now in progress, by which a part of the decayed vegetable covering of the earth is accumulated in peat bogs, lakes, estuaries, and the sea, we perceive clearly that if the production of coal be not now actually in progress in certain situations, deposits of carbonaceous substances happen under circumstances which will greatly contribute to correct and simplify our notions of the origin of that combustible.

Coal  
formed in  
various  
situations.

Until all the circumstances which characterise the different coal basins have been very fully investigated, it will be hazardous to decide generally against any hypothesis advanced to explain the deposition of coal, which proceeds upon observation of the accumulations of vegetable matter now in operation. It may hereafter appear that the vegetables of some coal basins grew where their remains are now carbonized, according to M. Brongniart's notion; that other coal beds arose from trees and plants, swept down from the land into fresh-water lakes; that others were formed in estuaries alternately traversed by floods from the land and tides from the sea; and that some were transported far into the deep and tranquil ocean.

But all the weight of observation yet made is de-

cidedly in favour of the opinion that the greater portion of all the carbonaceous deposits were swept down from the places where they grew on the land, to ancient lakes, estuaries, and seas; and, indeed, it is perhaps not yet made probable that any continuous bed of coal has been produced otherwise.

Generally  
not where  
the plants  
grew.

For De Luc's notion of the plants growing in the very spot where they have been converted to coal seems altogether inapplicable to cases where many layers of coal alternate with many of sandstones, shales, ironstones, &c. For this could only have happened, according to that notion, in consequence of at least as many subsidences and subsequent elevations of the same tract of strata, as there are coal seams in it; and when in addition we take into account the perfect parallelism of the strata indicating no disturbance, the thin laminae of coal which sometimes occur in the shales, the local divisions of the seams of coal, and the quantity of land plants lodged in the separating strata, we shall be compelled to limit to very few cases an hypothesis which involves such gratuitous difficulties.

1. On the contrary, these very circumstances are exactly such as must necessarily be occasioned by the effects of periodical floods operating through a long succession of time upon a well-wooded country. They would transport at intervals vast quantities of vegetable and mineral matter into the lowest receptacles of water. There the mingled mass would be sorted by the waters, according to bulk and specific gravity, as we observe every day in lakes and on the sea-shore, an effect which most probably would be much heightened by the unequal velocity with which masses of such unequal bulk and gravity would be originally transported by the current. They would be deposited in distinct layers, of which the most regular and uniform would be the layers of plants, because these are more different both as to bulk and specific gravity from the other materials brought along by the stream, than are these materials among one another; a fact remarkably conformable to observation.

2. But though the greater mass of the plants would be thus separated from the earthy sediment, there would probably be some portion unavoidably entangled therewith and deposited with them, and thus the sandstones and shale are found to contain in confused admixture a considerable number of plants.

3. The trees thus transported by the floods might for the most part not have been uprooted; they would also in their course be broken and mutilated, and mostly deprived of branches and leaves, exactly as we find them in the coal strata.

4. In the various eddies of the waters under which the sediment fell, some trees might be reared upright, and others might and indeed would float with the heaviest end downward, and be kept in that posture by a sudden and great accumulation of sediment, and thus we seem to have a natural explanation of the occasionally vertical position of trunks of sigillariae, and equisetaceae in sandstone. In shale deposited more tranquilly, this fact has never or most rarely been noticed.

5. Successive operations of this kind would equalize the results over a large area, and produce a remarkably general parallelism of strata in the same basin.

6. According to the condition of the currents, the accumulations at any given time, or for any period, might be in one part wholly vegetable, in another wholly earthy, or of alternate quality, and thus the occasional

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*deadness of a part of a coal tract usually productive, the division of a coal seam into its constituent portions, and the partings of a coal bed appear all perfectly natural consequences of the same simple cause.*

7. It is probable that in lakes which receive floods overcharged with sediment, and which in consequence are frequently muddy, few kinds of mollusca, or fishes, or other animals would live, and that the molluscons remains would be such only as belonged to bivalves, like unio and anodon, or univalves, like paludina, which never come to the surface for respiration, but remain at the bottom of the waters. The shells found in coal tracts, supposed to be of fresh-water origin, are principally uniones and anodonta.

8. It is also probable, for the same reason, that only a small number of the animals or plants actually existing in the sea at any one time would be found within the area of a very muddy estuary, and thus we see the reason why the coal basins which contain no fresh-water shells, and are from other circumstances presumed to be of marine origin, are generally devoid of animal remains, except in the calcareous layers or nodules which may occur in them. These calcareous deposits evidently mark periods during which the chemical precipitations from the sea were little or not at all troubled by the mechanical aggregations from the floods of the land.

9. As many basins of fresh water, estuaries, or seas, as received the vegetables and sediment brought down by the floods, so many distinct series of carbonaceous and argillo-arenaceous deposits would be produced;—there would be no *particular agreement* between them in the number, thickness, and quality and arrangement of the coal seams, rocks, or shales, or ironstone, but a *general agreement*, depending on the common physical conditions of the region. But in the *same basin*, even over very large areas, there would frequently occur *particular agreements*, in many respects; coals of particular quality, rocks of certain kinds, beds of ironstone, and layers of shells, may be traced over large tracts and assigned to definite places in the general section.

#### *Convulsive Movements of the Carboniferous System.*

Nothing appears more clear in Geology than that the same parts of the Globe have been alternately subject to gradual alteration, through the slow and equal action of the ordinary system of Nature, and to sudden extreme changes induced by the shorter dominion of violent disturbing forces.

The preceding descriptions sufficiently show how regular was the action of the causes which permitted the immense accumulations of chemical deposits, earthy sediment and vegetable reliquiae, on the beds of ancient lakes or estuaries, and for how long a period this process continued; the prodigious number of alternations in the deposits sufficiently attests. It was, indeed, compared to the present state of things, a period of remarkable excitement as to the vigour of vegetation, and perhaps also as to the abundance and force of inundations; but the parts of this series, compared with one another and with analogous strata of different ages, furnish proof that the whole was the result of what may be termed the then ordinary course of natural operations.

But this long period appears to have come suddenly to an end, and the characteristic regularity of its deposits to have been interrupted by a general eruption of disturbing forces which have left the traces of their power

and extent in all the coal fields of Europe and America. As after the deposit of the strata violent dislocations happened and were succeeded by the old red conglomerate, so after the deposit of the coal, similar and equally extensive interruptions of the planes and courses of strata were followed by the analogous deposit of new red sandstone. In the course of these operations, the whole thickness of at least the stratified mass of the crust of the Globe appears to have been broken in many directions, and the divided portions raised or depressed a few inches, many yards, or hundreds of fathoms from their former level, and placed in new situations, with various angles of inclination to the horizon, and in various directions. Scarcely a mine or colliery is worked in strata of this era in any part of the World which is not crossed by several faults or dislocations of this nature, and it is always found that they divide and displace in the same direction the whole series of the strata to the greatest depths which man has reached.

That these dislocations happened after the complete deposit and induration of the coal strata is evident; that they followed almost immediately, and happened nearly at the same period of time, in almost all the coal tracts, appears certain from the general fact, that the disturbances of the coal seams rarely extend into the newer strata of magnesian lime and red sandstone. There was, therefore, a general disturbing agency employed to break up the consolidated planes of the carboniferous strata; and from the occasional filling of the dislocations with basalt, various crystallized minerals, and other igneous products, no doubt can remain that the principal agent was that general source of heat which is included within our Planet, and which finds vent for its energies in different places at different times.

To particularize all, or even the most remarkable of the faults of the carboniferous systems of different Countries, and to notice all the variations of their appearance, would be entirely foreign to the intention of this treatise; such details must be sought in special descriptions of the several mining districts and coal fields. But we shall notice some of the most predominant of these dislocations, which appear to have caused the most extensive alterations in the level of the strata, and to have been most efficient in uplifting particular ranges of land, and giving new boundaries to the Ocean.

That most of the carboniferous deposits were originally hunted in area, has been already stated, and therefore we must be cautious not to infer the *violent* separation of two coal tracts from the mere fact of their disunion, without reference to the connecting inferior strata. Thus the coal fields of the Forth and the Clyde were probably limited by the previous elevation of the ranges of the Grampians and the Lammermuir, and though presenting strong analogies with the Northern coal fields of Northumberland, there is no reason to believe that they were ever joined to them. Keeping this in view, and guided by a knowledge of the *characteristic points* of the several systems of strata, we shall be able with more or less facility to determine the amount of the disturbance of position induced in any given coal tract, and thus to restore in imagination the original condition of the strata. The separation of the great coal fields of Northumberland and Durham on the one hand from those of Yorkshire and Derbyshire on the other, appears to have been caused by a general elevation in an Eastern and Western range of the whole of the tract intervening between Wharfedale and Teesdale.

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these dis-  
turbances.

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In consequence of this and the waste of the elevated surface, it happens that while the lower parts of the carboniferous system are connected, the upper parts are entirely divided, and the magnesian limestone lies level on the coal of Durham and millstone grit of Nidsdale, and again covers coal in Airedale.

Pendle  
chain.

Again, all of the great Northern carboniferous tracts are arranged with relation to an almost continuous Northern and Southern axis of elevation, from the mountains round the source of the South Tyne to Ingleborough, through Bolland forest, by Pendle hill and the Western border of Yorkshire, to the limestone district of Derbyshire, while the particular fields of Hartley Burn and Black Burton depend upon two cross lines of dislocation or fault, the former passing Eastward under the name of the main, or 90 fathom dyke, from near Brampton to the sea-side near Tynemouth, and depressing the strata to the North, while the latter ranges East South-East by a remarkable line of slate rocks from Kirby Lonsdale to near Grassington, and throws down to the South. The carboniferous rocks which surround the Lake mountains have certainly been affected by elevations subsequent to those which in that district followed the deposit of slate, and anterior to the deposit of the superincumbent red sandstone.

A large proportion of the mineral veins which divide the carboniferous limestone series of Aldstone Moor, and the mining dales of Durham and Yorkshire, range East and West, and may be reasonably viewed as lateral fissures proceeding from the main axis of elevation which they join nearly at right angles. The same direction at right angles to the continuation of the same principal axis of elevation is recognised in the veins of Derbyshire, some of which range to the North-East and others to the South-East, and, though with considerable variations, appears to prevail amongst the numerous faults or slips of the coal field of Yorkshire.

The great Northern and Southern axis of elevation of the carboniferous series in Derbyshire is broken across on the North, near Castleton, and appears to be terminated on the South near Bradbourn, by great cross faults; and the whole of the coal measures of Nottinghamshire and Derbyshire, on the East, and of Staffordshire on the West of the axis, are cut off by rapid dip or sudden depression to the South. It may be conjectured that the line of this depression is prolonged beneath the red rocks of Cheshire to the estuary of the Dee, and it is, perhaps, not improbable that the red marl and sandstone which fills the drainage of the Mersey covers a large extent of depressed coal strata.

Further researches may very probably ascertain the existence of several other buried coal tracts in the midland parts of England near the detached coal fields of Leicestershire, Warwickshire, and Staffordshire.

Forest of  
Dean.

The Forest of Dean is a singular basin of coal strata with a belt of mountain limestone and old red sandstone, rising from a plain of new red sandstone, and looking over the vales of Wye and Eski to the similar but more extensive district of South Wales. The general line of elevation in this immense coal field is East and West, and the strata dip from both the North and the South toward the middle; but Mr. Conybeare has shown that along the middle runs an internal axis of elevation, so that the coal field is a double trough.

The elevation of the Mendip Hills, and other tracts of carboniferous limestone in Somersetshire and Gloucestershire, as well as the curious faults in the collieries

near Bath and Bristol, must be referred to the same epoch, for the superior strata of red marl and the oolites are unaffected by them.

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This short review shows us what extensive changes in the relative level and area of land and water were effected in these regions immediately after the deposition of the coal strata, and similar results have been obtained from researches in various parts of Scotland, Arran, and other Islands, and in the large coal tracts in Ireland.

In extending our researches to foreign Countries, we must remember that the exact date of the disruption of the strata is determined by limiting the epoch between the date of the formation of the strata broken, and that of the unconformed stratum next incumbent or adjacent. Thus on passing from the Ardennes mountains to Luxembourg, we descend from the elevated slate range to a horizontal mass of new red sandstone, followed by lias and oolites; and in this case it is clear that the elevation of the Ardennes preceded the deposition of new red sandstone: but where that stratum is absent, (the general case along the border of these mountains,) we must have been content with inferring that the epoch of the disturbance was older than the oolites. On this account it is not easy to fix the date of the disturbances of the coal series of Belgium and the North of France more precisely than by saying, it was anterior to the oolites, since these are the oldest strata lying unconformably over the coal.

The slips and dislocations of the carboniferous system almost invariably agree as to the direction of their slope, compared to the level of the strata with the general law stated before: (ch. i. p. 541.) but there are a few cases of such extraordinary dislocation, as at Valenciennes and in Somersetshire, that the beds of coal and accompanying strata are bent into a sigmoidal flexure, and in part turned completely upside down. Lesser cases of flexure of beds are not unfrequent.

With respect to the degree of distinctness of the planes of the slip, we may remark that this depends very much upon the consolidation of the strata divided. Thus while in limestone and solid sandstone the planes or cheeks of the slip are clearly traced, they are almost obliterated in shales and thin bedded sandstones, either by a bending at the surface of fracture, or by a filling up of the chasm irregularly with fragments from the sides. This applies even to the case of a mineral vein which crosses alternating strata of three different kinds, as in the mines of Aldstone Moor and Swaledale, where the metallic and sparry substances are crystallized in abundance in the open space between the hard cheeks of limestone and gritstone, but are far less plentiful in the obscure and contracted interval between faces of shale. In districts which appear to have been once remarkably subject to igneous eruptions, the fissures of the dislocations are often filled by basalt, both in the subjacent limestone and superior coal tracts, as in the Counties of Durham and Northumberland; but the metallic ores and spars which properly constitute a mineral vein, and which abound so much in the limestone as to give it the name of metalliferous, are very seldom found in the fissures of the coal tract.

However it is to be explained, there certainly appears to be some affinity between the metallic matter of the vein and the nature of the strata which it traverses; and though no doubt can be entertained that the veins

Affinity between veins and rocks.

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are posterior to their including rocks, the frequent passage of *strings of ore* into the neighbouring strata, occasional nodiform masses, and solitary crystals of the metallic substances embedded in the interior of the rocks, besides the very remarkable examples of crystals of blende, galena, &c. in the interior of brachiopodous bivalves, seem to prove that the metallic matter has been in these cases deposited by a kind of *secretion*. Nor is this supposition, which is strongly confirmed by observations in the slate districts of Cornwall, in the least inconsistent with what is known of the diffusion of metallic substances by gradual heat much below their melting points. Breislac and Henry mention cases of the transference and collection of metallic matter (copper) at an ordinary roasting heat, and the well-known example of titanium extricated from the melted iron of

our furnaces leads to analogous conclusions. We may, therefore, very consistently maintain, that mineral veins are posterior to the strata which they divide, and yet allow that the transference of metallic substances may have been effected by the ordinary agency of heat, or the influence of electricity, so as to impregnate the strata under particular circumstances with the contents of the neighbouring veins. Such secretions of metallic substances then do not require us to admit the contradictory dogma that the veins occupying fissures are contemporaneous with the strata.

The metallic substances usually yielded by the carboniferous limestone are most of the ores of lead, zinc, and copper, with oxides and carbonate of iron, and the vein-stuff, or matrix, is calcareous spar, fluor spar, sulphate and carbonate of barytes, strontianite, quartz, &c.

### Organic Remains of the Carboniferous System.

The mark \* signifies that the species to which it is attached has been stated to occur in the slate system also

#### PLANTS.

Family	Name	British Localities	Foreign Localities
Algae	<i>Equisetum intumescens</i>	.....	Saarbrück.
	<i>dubium</i>	Wigan.	Ditto.
	<i>(Camarotoechia) conatus</i>	Yorkshire	Ditto.
	<i>Suckowia</i>	Newcastle	{ Ditto Liege, Anzin, Litry, Richmond in Virginia, Wilkesbarre, Pennsylvania.
	<i>undulatus</i>	Yorkshire	Radnitz in Bohemia
	<i>ramosus</i>	Ditto	Mannbach, Wettin, Germany.
	<i>cruciat</i>	.....	Litry, Saarbrück
	<i>Cisti</i>	.....	Wilkesbarre, Montclair, Saarbrück
	<i>dubius</i>	Ditto	Zanesville in Ohio.
	<i>canaliculatus</i>	Ditto, Newcastle	{ Lingua, (H. Lone,) Alais, Mannbach, Wettin, and Radnitz, in Germany.
	<i>pachydictya</i>	.....	St. Etienne.
	<i>modicus</i>	Newcastle	La Gardin, Departement de la Dordogne.
	<i>approximatus</i>	.....	Alais, Liege, St. Etienne, &c
	<i>Stemmatium</i>	Yorkshire	.....
Fossils	<i>(Mongotia) turcata</i>	Edinburgh	Charleroi, Silesia, Saarbrück
	<i>Sphenopteris turcata</i>	Newcastle	Waldenburg in Silesia.
	<i>elegans</i>	.....	.....
	<i>stricta</i>	Ditto, Glasgow	.....
	<i>reticulata</i>	Newcastle	.....
	<i>delicatula</i>	.....	Saarbrück, Radnitz.
	<i>diversa</i>	.....	{ Montclair, St. George (Chatellaison) St. Hippolyte in the Vosges.
	<i>linearis</i>	.....	Swana, in Bohemia
	<i>Brach</i>	.....	Lo. Lunda.
	<i>nervosa</i>	.....	.....
	<i>trifoliata</i>	Yorkshire (Artis)	Anzin near Valenciennes, Mons, Liege, Silesia.
	<i>lenticulata</i>	.....	.....
	<i>Schlotthumia</i>	.....	{ Dautwich near Saarbrück, Waldenburg, and Bräun-chenbach in Silesia.
	<i>fragilis</i>	.....	Bräunchenbach.
	<i>Henningshausia</i>	Newcastle	Werden
	<i>Dubiussonia</i>	.....	Montclair
	<i>distans</i>	.....	Silesia, Ilmenau
	<i>gracilis</i>	Ditto.	.....
	<i>Gravenhorstia</i>	.....	Silesia
	<i>Loshii</i>	Ditto	.....
	<i>latifolia</i>	Ditto.	.....
	<i>Viretia</i>	.....	St. George Chatellaison.
	<i>affinis, Lind.</i>	Ditto	.....
	<i>bifida, Lind.</i>	Edinburgh.	.....
	<i>caudata, Lind.</i>	Newcastle.	.....
	<i>crenata, Lind.</i>	Ditto	.....
	<i>erithmitolia, Lind.</i>	Ditto.	.....
	<i>dilatata, Lind.</i>	Ditto.	.....
	<i>Cyclopteris orbicularis</i>	.....	St. Etienne, Liege.
	<i>auriculata</i>	Yorkshire.	.....
	<i>flabellata</i>	.....	Berghaupten.
	Several species of Cyclopteris are found at Liege.		
	<i>Neuropteris acuminatus</i>	Newcastle	Klein Schmalkalden.
	<i>Villiersii</i>	.....	Alais. (Departement du Gard.)
	<i>Cisti</i>	.....	Wilkesbarre in Pennsylvania.
	<i>rotundifolia</i>	Yorkshire	Mine du Pissis. (Calvados.)
	<i>Loshii</i>	Newcastle	Anzin, Liege, Wilkesbarre.

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	<i>Filices</i> .....	<i>Neuropteris tenuifolia</i> .....		{ Saarbruck, Mierschach, (Bohemia,) Waldenburg, (Silesia,) Montrelais.	
		<i>heterophylla</i> .....	Newcastle	Saarbruck, Valenciennes.	
		<i>Grangeri</i> .....		Zanesville. (Ohio.)	
		<i>flexuosa</i> .....	Bath, Yorkshire, &c.	Saarbruck.	
		<i>gigantea</i> .....	Newcastle	Anzin, Saarbruck, Eschweiler, &c.	
		<i>oblongata</i> .....	Paulton, Somerset		
		<i>cordata</i> .....	Leebotwood, near Shrewsbury	Alais, St. Etienne.	
		<i>Soretii</i> .....	Newcastle.		
	<i>Pecopteris longifolia</i> .....			Werden, near Dusseldorf, St. Priest. (Loire)	
		<i>blechnoides</i> .....		Alais. (Gard.)	
		<i>Candolliana</i> .....		St. Etienne.	
		<i>rynthea</i> .....		St. Etienne, Aubin, (Aveyron,) Anzin, Mannebach.	
		<i>arborescens</i> .....		St. Etienne.	
		<i>platyrachis</i> .....		Charleroi.	
		<i>Dithensis</i> .....		St. Etienne, Alais; Litry, (Calvados?) Wilkesbarre.	
		<i>polymorpha</i> .....		Le Lardin, Mannebach, Wettin.	
		<i>oreopteroides</i> .....			
		<i>Bucklandi</i> .....	Bath.	Mannebach and Wettin.	
		<i>aquilina</i> .....		Mannebach, Geislaunern.	
		<i>Schlotthemmi</i> .....		Mannebach, Aubin.	
		<i>pteroides</i> .....		Liege, Valenciennes.	
		<i>Duvrouxi</i> .....		Liege.	
		<i>Mantelli</i> .....	Newcastle	Saarbruck, Silesia, Namur.	
		<i>lonchitica</i> .....	Ditto	St. Etienne, Wilkesbarre, Geislaunern	
		<i>Serli</i> .....	Bath.	Geislaunern.	
		<i>Grandini</i> .....		Ditto	
		<i>crenulata</i> .....		Alais.	
		<i>marginata</i> .....		{ Abascherhutte, (Tieves,) Saarbruck, Wilkesbarre, Liege.	
		<i>gigantea</i> .....		Montagne des Rousses, (Osans,) Wilkesbarre.	
		<i>punctulata</i> .....		Waldenburg, Rolduc, Liege, Wales.	
		<i>neivosa</i> .....		Valenciennes.	
		<i>obliqua</i> .....		Larhin.	
		<i>Brardi</i> .....		Saarbruck.	
		<i>Defrancoi</i> .....		St. Etienne.	
		<i>ovata</i> .....		Alais, St. Etienne.	
		<i>Plukenetii</i> .....		St. Etienne, Saarbruck, Rhode Island	
		<i>arguta</i> .....		New South Wales.	
		<i>alata</i> .....		Saarbruck.	
		<i>crustata</i> .....		Montrelais.	
		<i>* aspera</i> .....		Saarbruck.	
		<i>Miltoni</i> .....	Yorkshire.	Valenciennes.	
		<i>abbreviata</i> .....		Saarbruck.	
		<i>microphylla</i> .....		Fresnes and Vieux Condé, near Valenciennes, Silesia.	
		<i>æquebis</i> .....		Saarbruck, Ronchamp (Haute-Saône)	
		<i>acuta</i> .....		Geislaunern, St. Etienne.	
		<i>nuda</i> .....		Mines de Ronchamp.	
		<i>debilis</i> .....		Valenciennes, Dautwell.	
		<i>dentata</i> .....		Swina, (Bohemia,) Saarbruck.	
		<i>angustissima</i> .....		Geislaunern, Valenciennes.	
		<i>gracilis</i> .....		Fresnes and Vieux Condé, Saarbruck.	
		<i>penniformis</i> .....		Fresnes and Vieux Condé.	
		<i>triangularis</i> .....		Geislaunern.	
		<i>pectinata</i> .....		Saarbruck, Valenciennes.	
		<i>plumosa</i> .....	Ditto		
		<i>adiantoides</i> , Lind. ....	Newcastle.		
		<i>heterophylla</i> , Lind. ....	Ditto.		
	<i>Lonchopteris Dournaisi</i> .....			Valenciennes.	
		<i>caucellata</i> .....			
	<i>Odontopteris Brardi</i> .....			Le Lardin and Terrasson, (Dordogne,) St. Etienne.	
		<i>crenulata</i> .....		Terrasson	
		<i>minor</i> .....		St. Etienne, Le Lardin.	
		<i>obtusa</i> .....	Near Shrewsbury	Terrasson.	
		<i>Schlotthemmi</i> .....		Mannebach, Wettin.	
	<i>Canlopteris prunawa</i> , Lind. ....		Somersetshire.		
	<i>Schizopteris anomala</i> .....			Saarbruck.	
<b>Lycopodiaceæ</b> .....	<i>Lycopodites piniiformis</i> .....			Saxe Gotha, St. Etienne.	
		<i>polyphyllus</i> .....		Silesia.	
		<i>Gravenhorstii</i> .....		Hadley on the Connecticut.	
		<i>Sillimanni</i> .....		Eisleben.	
		<i>Hæninghausi</i> .....		St. George Chatellaisson.	
		<i>umbriatus</i> .....		Silesia.	
		<i>phlegmarioides</i> .....	Newcastle	St. George Chatellaisson.	
		<i>tenuifolius</i> .....		Wettin.	
		<i>fliciformis</i> .....		Ditto.	
		<i>affinis</i> .....			
	<i>Selaginites patens</i> .....		Edinburgh.	Mont Jean, near Angers.	
		<i>erectus</i> .....		Bohemia, Silesia.	
	<i>Lepidodendron selaginoides</i> .....		Newcastle	Swina, Bohemia.	
		<i>elegans</i> .....			
		<i>Bucklandi</i> .....	Colebrook Dale.		

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	Lycopodiaceæ	Lepidodendron ophiurus	Newcastle	Charleroi.	
		rugosum		Ditto, Valenciennes.	
		Underwoodii	Anglesea.		
		taxifolium		Ilmenau.	
		insigne		St. Ingbert in Bavaria.	
		Sternbergii	Newcastle	Swina in Bohemia.	
		longifolium		Ditto.	
		mamillare		Wilkesbarre.	
		ornatissimum	Edinburgh, Yorkshire	Silesia.	
		tetragonum	Newcastle.		
		venosum		Waldenburg. (Silesia.)	
		transversum	Glasgow.		
		Volkmannianum		Silesia.	
		Rhodanum	Yorkshire	Ditto, Valenciennes.	
		cordatum	Durham		
		obovatum		{ Radnitz, (Bohemia,) Silesia, Fresnes, and Vieux Condé.	
		dubium	Newcastle.		
		laeve		Comté de la Marche.	
		pulchellum		Alais, Liege.	
		celatum	Yorkshire.		
		varians		Wilkesbarre, Saarbruck.	
		carinatum		St. George Chatellais, Montrelais.	
		crenatum		Bohemia, Eschweiler, Essen, Zanesville. (Ohio.)	
		aculeatum		Essen, Wilkesbarre, Bohemia, Silesia.	
		Cisti		Wilkesbarre.	
		distans		St. Etienne.	
		lanceolatum		Bohemia, Silesia.	
		rimosum.		Bohemia.	
		undulatum		Ditto.	
		confluens		Silesia, Eschweiler	
		Harcourtii, With.	{ Northumberland (C. V.		
		umbricatum	{ Harcourt.)	Eschweiler, Wettin.	
		acerosum, Lind.	Newcastle.		
		dilatatum, Lind.	Ditto.		
		gracile	Ditto.		
		Lepidophyllum majus		Geislauntern.	
		lanceolatum		Montrelais.	
		Boblayi		Valenciennes.	
		timerve		Montrelais.	
		lineare		Alais.	
		intermedium, Lind.	Near Shrewsbury.		
		Lepidostrobus ornatus	Shropshire.		
		undulatus	England.		
		emarginatus	Yorkshire.		
		major	Newcastle.		
		variabilis, Lind.	Ditto.		
		Cladodendron majus, Lind.	Barnsley, near Newcastle		
		minus, Lind.	Halifax, Craighith, Shields		
		Cardiocaulon majus		St. Etienne, Langeac. (H. Loire.)	
		Pomieri		Langeac.	
		cordiforme		Ditto.	
		ovatum		Ditto	
		acutum	Newcastle	Ditto.	
		Stigmarna reticulata	England.		
		Weltheimiana	Magdeburg.		
		regularis	Germany.		
		intermedia		St George Chatellais, Montrelais, Wilkesbarre.	
		*ficoides	{ Leeds, Durham, North-	{ St. George Chatellais, Montrelais, St. Etienne.	
			berland, Derbyshire, &c.	{ Liege, Charleroi, Valenciennes, Muhlheim near Dusseldorf, Silesia, Bavaria.	
		tuberculosa		Montrelais, Wilkesbarre.	
		rigida		Anzin.	
		minima	Anglesea	Charleroi.	
		Sigillaria punctata		Bohemia.	
		appendiculata	Yorkshire	Ditto.	
		peltigera		Alais.	
		Cisti		Wilkesbarre.	
		laevis		Liege.	
		canaliculata		Saarbruck.	
		rugosa		Wilkesbarre.	
		Cortei		Essen.	
		elongata		Charleroi, Liege.	
		reniformis	Newcastle.	Mons, Essen.	
		hippocrepis		Mons.	
		Davreuxii		Liege.	
		Candolli		Alais.	
		oculata	Ditto	Bohemia.	
		orbicularis		St. Etienne, Saarbruck.	
		* tessellata	Bath, Yorkshire, Newcastle.	Alais, Eschweiler, Wilkesbarre.	

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	Cactaceae	<i>Sigillaria</i> Bohlayi		Anzin.
		Kuorrii		Saarbruck.
		elliptica		St. Etienne.
		transversalis		Eschweiler near Aix la Chapelle.
		pyriformis		Wilkesbarre.
		Sillimanni		Doutweiler, near Saarbruck.
		subrotunda		St. Etienne.
		cuspidata		
		scutellata		
		pachyderma	Yorkshire.	
		notata		Saarbruck, Silesia, Liege.
		Dournaisii		Charleroi, Valenciennes.
		trigona		Radnitz in Bohemia.
		mamillaris		Charleroi.
		alveolaris		Saarbruck.
		hexagona		Borckum, near Essen, Eschweiler.
		elegans		Borckum.
		ornata		
		Menardi.		Terrasson.
		Brardi		Montrelais.
		laevigata		Wilkesbarre.
		obliqua		Ditto.
		dubia		
		Defranci		
		Serrii	Paulton.	
		organum, Sternb.	Newcastle.	
		monostachya	Cramlington, Northumber- land.	
Conifers		<i>Sphenophyllum</i> Schlottheimi		Waldenburg, Silesia.
		emarginatum	Bath	Wilkesbarre.
		truncatum	Somerset.	
		dentatum	Newcastle	Anzin, Geislautein.
		fimbriatum		
		quadridum		Terrasson.
		dissectum		Montrelais, St. George Chatellaisson.
		erosum, Lind.	Ditto.	
		<i>Platan</i> Brandlugi, Lind.	Ditto.	
		Withami, Lind.	Edinburgh.	
		medullaris, Lind.	Ditto.	
		ambiguus, With.	High Heworth.	
		<i>Pitys</i> antiqua, With.	Lennel Braes, near Gold- stream.	
		<i>Anabathra</i> pulcherrima, With.	Tweed Mill	
		Peuce Withami, Lind.	Durham.	
Palma		<i>Flabellaria</i> ? borassifolia		Swina in Bohemia
		<i>Nagegerrathia</i> foliosa		Bohemia.
		flabellata	Newcastle.	
		<i>Zeugophyllites</i> ca' amoides		Rana Gunje, near Rajemahl, India.
Canna		<i>Cannophyllites</i> Virletii	Yorkshire.	
		<i>Sternbergia</i> angulosa	Ditto.	
		approxinata		Langreac, St. Etienne
		distans	Edinburgh.	
		<i>Poacites</i> lanceolata		Zanesville. (Ohio)
		aqualis		Terrasson.
		striata		Ditto.
Glumaceae		<i>Cyperites</i> bicarinata, Lind.	New Shrewsbury	
		<i>Trigonocarpon</i> Parkinsonis	England, Scotland.	
		Nagegerrathi		Langreac, Coal Mines on the Rhine
		ovatum		Ditto.
		cylindricum		Ditto.
		dubium		Ditto.
		<i>Musocarpum</i> prismaticum		Ditto.
		difforme		Ditto.
		contractum	Oldham.	
(Class doubtful)		<i>Phyllothea</i> australis		Hawkesbury River, New Holland.
		<i>Annularia</i> minuta		Terrasson.
		brevifolia		Alais, Geislautein.
		fertilis	Bath	St. Etienne, Wilkesbarre.
		floribunda		Saarbruck.
		longifolia	Camerton	Geislautein, Silesia, Alais, Wilkesbarre.
		B		Charleroi, Terrasson.
		spinulosa		Saxony.
		radiata		Saarbruck.
		<i>Asterophyllites</i> equisetiformis		Mannebach, (Saxony,) Rhode Island.
		rigida		Alais, Valenciennes, Charleroi, Bohemia.
		hippuroides		Alais.
		longifolia	Newcastle	Eschweiler.
		tenuifolia	Ditto.	Silesia.
		tuberculata	Ditto.	Germany.
		denticulata		Charleroi, Anzin.

Geology. Ch. II.	Family.	Name.	British Localities.	Foreign Localities.
	(Class doubtful.)	<i>Asterophyllites Brardi</i> .....	Terrasson.	
		<i>dubia</i> .....	Newcastle.	
		<i>diffusa</i> .....	.....	Radnitz, Bohemia.
		<i>grandis</i> , Lind. ....	Ditto.	
		<i>foliosa</i> , Lind. ....	Ditto.	
		<i>galioides</i> , Lind. ....	Barnsley.	
		<i>Volkmannia polystacha</i> .....	Waldenburg (Silesia.)	
		<i>distachya</i> .....	Swina. (Bohemia.)	
		<i>corona</i> .....	Terrasson.	
		<i>Polyporites Bowmanni</i> , Lind. ...	Near Wrexham.	

Nearly all the names of fossil plants are taken from Brongniart; the few from Lindley and Hutton, from Sternberg and Witham, are marked by suitable abbreviations.

Analogy to  
existing  
plants.

The following observations by M. Adolphe Brongniart contain nearly all that can be at present advanced concerning the physical conditions which governed the growth of these plants. We shall first remark that since the date of M. Brongniart's Essay, true conifers have been discovered in the English coal districts, and that his reference of sigillaria to the tribe of arborescent ferns appears open to very serious objections, and is perhaps not generally allowed. Besides the few coniferæ and monocotyledones, "the flora of this epoch is composed almost wholly of vascular cryptogamous plants, so that out of 260 species 220 belong to this class. But, though evidently ranging themselves in the families of equisetaceæ, filices, and lycopodiaceæ, these plants differ from the species, and often from the genera now in existence, in several points of their organization, and especially by their gigantic size. At this period there existed equiseta more than ten feet in height, and five or six inches in diameter, tree ferns forty or fifty feet, and arborescent lycopodiaceæ sixty or seventy feet high. The essential characters of this 'primary' vegetation are the numerical predominance and great magnitude of these cryptogamic plants.

"It has been long observed, that the plants of this age resembled generally those of the hot, rather than of the temperate regions of the Globe; but since the fossil plants have become much better known, and their analogy with existing tribes founded upon a more thorough examination, their relation to the plants of Equatorial regions may be established on a more solid basis. All cryptogamic plants acquire greater size, in proportion as the climate is hotter; or rather, in cold climates none but very small species of this class are found, while in tropical regions we have, in addition, many of large size. The ferns of cold and temperate climates are upon the soil, or their stem rises only a few inches in height; those of tropical regions grow to ten or twenty feet: the smallest equiseta known are those of Lapland and Canada; the largest grow in the West Indies, and Equinoxial America; the lycopodia of our climates are never above five or six inches high, those of tropical regions are three or four times as high.

"The numerical predominance of the cryptogamic tribes in the carboniferous epoch is such that, while in the existing order of Nature they are to the whole number

of plants known as 1 to 30, they were in that ancient epoch in the proportion of 27 to 30."

If we seek to determine by comparison with particular or local existing floras, the probable circumstances under which cryptogamic plants grew to such preponderance in the carboniferous epoch, we shall be guided by the observations of Brown and D'Urville to some important results. According to these eminent Botanists, the family of ferns is subject to the influence of two causes, which determine their mode of distribution over the Globe; heat of climate, and the influence of the humid air and uniform temperature of the sea. Hence, when the circumstances depending on proximity to the sea are equal, these plants are more abundant in the Equatorial than in colder regions, but in the same zone of climate they are much more abundant in isles than on continents. In the temperate parts of the Continent of Europe, under favourable circumstances, they are to the phanerogamic tribes as 1 to 40; within the tropics Brown states the ratio as 1 to 20, and in unfavourable situations as 1 to 26. Under the same latitude, this proportion becomes much greater in Islands; in the West Indies the ratio is as 1 to 10, instead of 1 to 20, as in favourable situations on the Continent of equinoxial America; in the South Sea Islands 1 to 4, or 1 to 3; while on the Continent of India and in the tropical part of New Holland the ratio is 1 to 26. At St. Helena and Tristan d'Acugna the cryptogamia are to the phanerogamia as 2 to 3, and in Ascension nearly as 1 to 1.

From these examples it is plain, that the smaller the isles, and the more remote they are from great continents, the larger is the proportion of ferns growing there; and we may conceive that if such islands were alone in the midst of a vast ocean, or formed only scattered points or little clusters without any great continent, their proportion of ferns would be still greater, and the cryptogamia become the predominant group. Geologists have, from independent considerations, inferred that at the time of the formation of coal, the extent of land in the position of our present continents was very small compared to the wide surface of the sea; and thus Geology and Botany appear to agree in determining that at this period, and in the situations where afterwards coal was formed, land existed only in small islands, amidst extensive seas. On these islands, under perhaps a more than tropical climate, in an atmosphere charged with moisture, we may believe that those gigantic cryptogamia grew which have produced so large a proportion of the extended coal beds of the older carboniferous epoch.

## POLYPARIA.

Family.	Name.	British Localities.	Foreign Localities.
Cellulifera .....	<i>Flustra crinoides</i> , Milner. ....	Arran.	
	<i>Rotopora flustriformis</i> , Murf. ....	Middleton, Derbyshire, Arran.	
	<i>elongata</i> , F. ....	Lutherglen, Lanark.	
	<i>Collepora Urii</i> , F. ....	Lutherglen.	
	<i>Aulopora compressa</i> , G. ....	.....	Ratingen.
	<i>Catenipora</i> .....	Winstan.	



Geology. Ch. II.	Family.	Name.	British Localities.	Foreign Localities.
	Cellulifera	<i>Tubipora ramulosa</i> .....	Mendip, Westmoreland, Ireland.	Oine, Limburg.
		<i>Syringopora reticulata</i> .....	Winster.	Oine.
		<i>radiata</i> , Mart. ....	Westmoreland.	
		<i>strues</i> , L. ....		
		<i>tubularia</i> L. ....		Liege.
		<i>Favosites septosus</i> , F. ....	Scotland.	
		<i>depressus</i> , F. ....	Ditto.	
		<i>ramosus</i> .....	Arran.	
		* <i>Calamopora polymorpha</i> , G. ....		Namur, Eiterfeld.
		<i>Millepora</i> , undescribed, Sp. ....	Near Kirby Lonsdale, in thin beds.	
		undescribed, Sp. ....	{ Near Middleham, near Kirby Lonsdale.	
Lamellifera		<i>Cyathophyllum excentricum</i> , G. ....		Ratingen.
		<i>pentagonum</i> , G. ....		Namur.
		<i>Lithostrotion striatum</i> , Park ....	Wales.	
		<i>floriforme</i> , Mart. ....	Bristol.	
		<i>marginatum</i> , F. ....	Scotland.	
		<i>Caryophyllia fasciculata</i> .....	Bristol	At Namur two species of <i>Caryophyllia</i> .
		<i>duplicita</i> , Mart. ....	Bakewell.	
		<i>affinis</i> , Mart. ....	Winster	
		<i>juncica</i> , F. ....	Rutherglen	
		<i>Turbinolia fungites</i> , F. ....	Yorkshire, Rutherglen, Ireland	Liege, Namur.
		<i>Astræa undulata</i> , Park ....	Bristol.	
		<i>Porites cellulosa</i> , Park ....	Mendip.	
		* <i>Amplexus coralloides</i> , Sow. ....	Anglosen, Limerick.	

These thirty or more species of polyparia appear of Belgium and Westphalia. No polyparia have yet almost wholly distinct from those of the slate system, been seen in the proper coal measures; they all belong yet they belong mostly to the same genera. They have to the subjacent limestone group. as yet been little noticed in the carboniferous limestone

## RADIARIA.

Family.	Name.	British Localities.	Foreign Localities.
Crinoidæ	<i>Poptremites ellipticus</i> , Sow. ....	Preston.	
	<i>Derbiensis</i> , Sow. ....	Derbyshire, Ireland.	
	<i>globosus</i> .....	Bath.	
	undescribed species ....	Craven in Yorkshire.	
	<i>ovalis</i> , G. ....		Ratingen, Dusseldorf.
	<i>Poteriocrinus crassus</i> .....	Yorkshire, &c. Bristol, Arran.	
	<i>tenuis</i> .....	Mendip, Bristol.	
	<i>Platycrinus lavis</i> .....	Bristol, &c.	
	<i>rugosus</i> .....	Mendip, Cald Island, Whitwell.	
	<i>tuberculatus</i> .....	Mendip, Whitwell, Yorkshire.	
	<i>granulatus</i> .....	Ditto, ditto, ditto.	
	<i>striatus</i> .....	Bristol.	
	* <i>pentangularis</i> .....	Ditto, Mendip.	
	<i>depressus</i> , G. ....		Ditto.
	<i>Cyathocrinus planus</i> .....	Northumberland.	
	<i>quinquangularis</i> .....	Bristol.	
	* <i>rugosus</i> .....	Whitwell, Yorkshire.	
	<i>Actinocrinus</i> *30 <i>dactylus</i> .....	Ditto, ditto, Ireland.	
	<i>polydactylus</i> .....	Whitwell, Mendip.	
	<i>lævis</i> .....		Ditto.
	<i>Gilbertsoni</i> .....	Whitwell, Yorkshire.	
	<i>grandilatus</i> , G. ....		Ditto.
	<i>Rhodocrinus</i> * <i>verus</i> .....	Whitwell, Bristol, Dean Forest.	
	<i>quinquangularis</i> .....	Whitwell.	
	<i>Eugenocrinus</i> , undescribed ....	County Fermanagh, Ireland.	
Echinida	<i>Ularis</i> , with large mammiellæ and mu- ricated spines. ....	{ Phil. MS. { Yorkshire, Northumberland. Westmoreland.	

No radiaria have yet been seen in the proper coal measures, they all belong to the subjacent limestone group, which in some extensive tracts is almost wholly composed of their disjointed columns and other parts. The names are principally from Miller's Work on the crinoidæ; where other authors are quoted, their names are appended to the particular species described by them.

## CONCHIFERA.

Family.	Name.	British Localities.	Foreign Localities.
Plagymyona	* <i>Pholadomya</i> ? undescribed, Sp. ....	Castleton.	
	<i>Corbula limosa</i> , F. ....	Scotland.	
	<i>Sanguinolaria gibbosa</i> .....	Queen's County, Ireland.	
	<i>Tellina lineata</i> , H. ....		Ratingen.
	<i>Cardium</i> * <i>alæforme</i> .....	{ Isle of Man, Arran, Queen's County.	
	<i>Hibernicum</i> .....	Cork, Mendip.	
	<i>elongatum</i> .....	Bakewell, Whitwell, &c.	
	<i>Hiatella sulcata</i> , F. ....	Frith coal field, North Britain.	
	<i>Isocardia oblonga</i> .....	Dublin.	

Geology. Ch. II.	Family.	Name.	British Localities.	Foreign Localities.
	Plagymyona	Cypricardia annulata		Visé, near Liege.
		Nucula palmæ	Derbyshire.	
		attenuata, F.	Shale Rutherglen.	
		gibbosa, F.	Ditto.	
			Northumberland.	
		Anodon? crassus	Wigan. Leeds?	
		Uno Uri, F.	Coal Rutherglen.	
		subconstrictus	Yorkshire, Newcastle, &c.	Liege.
		acutus	Ditto, ditto	Ditto, Werden, Roosum.
		other species	Yorkshire, Derbyshire.	
		Chama? antiqua, H.		Ratingen.
		Modiola levie	Barry Isle	
		undescribed	Castleton.	
		Goldfuss, H.		Ditto, Visé.
		Megalodon *cucullata	Yorkshire	
Memomyona		Mytilus crassus, F.	Shale. Cult hills, Fife, Wigan	Werden,
		ca. v. R.		Near Cologne.
		P. ...	Ashford	Ratingen.
			Castleton	Ditto.
			Ditto, Yorkshire, Ireland	Ditto.
			Queen's County	
			Ditto.	
			Scotland.	
			Leeds, Sheffield, Halifax	Liege, Werden
			Northumberland	
			Ditto.	
			Brad. Sheffield	Visé, near Liege
			Clas. in Craven, Yorkshire,	
			Ireland	
			Bradford, Yorkshire.	
				Visé
				Ratingen
Brachiopoda		Modiola reflexa?	Ironst. Coalbrook Dale	
		undescribed species	Northumberland	
		Terebratula acuminata	Buxton, Scalebar, Clithero, &c.	Ditto.
		*crumena	Wimster.	
		*pugnax	Coom, Ireland, &c., Clithero.	
		*platylaba?	Clithero.	
		*lateralis	Black Rock, Cork, Dublin	Ditto.
		*Mantua	Ireland	
		*cordiformis	Ditto.	
		*reniformis	Dublin	Ditto
		hastata	Bristol, K. L. &c	
		*sacculus	Middleton, Matlock, K. L.	
		dubia, D.	Ireland	
		Dorass, D.	Dublin.	
		? indentata		Ditto, Visé.
		obliqua		Ratingen
		monticulata, Schl.		Visé.
		*hevigata, Schl.		Ditto
		Spindera resupinata (Tereb. Sow.)	Dovedale, Clithero, Rutherglen	Ratingen.
		Mutton	Castleton, Bristol.	
		*cuspidata	Ditto	Ditto.
		trigonalis	Caydale and Overton	Visé, Ratingen.
		trigonalis	Buxton, Derbyshire	
		*trigonalis	Arran (East Thukley,*)	
		*trigonalis	Ditto	Ditto.
		*trigonalis	Chelmerton and Ireland	Ratingen.
		*trigonalis	Bakewell, Arran	Namur, Ratingen, Liege.
		*trigonalis	Ditto	Ratingen
		*trigonalis	Ditto.	
		*trigonalis	Scalebar, Yorkshire.	Ditto, Liege.
		*trigonalis	Castleton.	
		*trigonalis	Ditto, Little	Ditto, ditto
		*trigonalis	Flintshire, Derbyshire	Visé, Liege.
		*trigonalis	Black Rock, Ireland.	
		*trigonalis	Ditto.	
		*trigonalis	Ditto	Visé.
		*trigonalis	Ditto	
		*trigonalis	Torquay, Limerick	Ditto.
		Uta	Rutherglen.	
		exata, F.	West Lothian	
		hastata, G.		Ratingen.
		hastata, G.	Walsingham.	
		hastata, G.	Rutherglen.	
Prodrus		*longispina	Edinburgh, Lanarkshire.	
		*longispina	Edinburgh	Ditto, Visé.
		*longispina	Livingstone, ditto.	
		*longispina	Ditto, Arran	Ratingen.
		*longispina	Edinburgh, Arran, Isle of Man	Liege, Visé

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Family.	Name.	British Localities.	Foreign Localities.
Brachiopoda....	Producta aculeata .....	Bakewell.	
	gigantea .....	Ditto, Yorkshire.	
	*scabricula .....	{ Milldale, Derby, Arran, North } { Cumberland .....	Visé.
	*Martini .....	{ Derbyshire, Ashford, Arran } { Yorkshire .....	Ratingen, Visé.
	crassa .....	Buxton, Derby.	
	striata .....	Croon, Ditto.	
	semireticularis .....	Derbyshire.	
	antiquata .....	Ditto, Dublin. ....	Ditto, ditto.
	*sulcata .....	Ditto .....	Visé, Liege.
	personata .....	Ditto, Kendal .....	Ratingen.
	punctata .....	Buxton, Yorkshire, Ireland .....	Visé, Ratingen
	finibata .....	Derbyshire, Yorkshire .....	Ratingen, Visé.
	plicatilis .....	Ditto .....	Ratingen, Liege.
	*horrida .....	Arran.	
	hemispherica .....	Mynold Carrig, Yorkshire .....	Ratingen, Visé, Liege.
	comoides .....	Llangavenn, Anglesea .....	Ratingen
	latissima .....	Puffin Island, Arran .....	Ditto, Visé, Liege
	concinna .....	Richmond, Derbyshire .....	Ditto, ditto
	lobata .....	{ Clifton, Cumberland, Northum- } { berland, Arran .....	Ditto, ditto, ditto
	costata .....	Gloucestershire, Glasgow.	
	humerosa .....	Bredon, Derbyshire .....	Ratingen.
	Crania prisca, II. ....		Ditto.

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The names in the preceding catalogue of conchifera are almost wholly taken from Sowerby's *Mineral Conchology*; where other authors are quoted, their names are appended to the particular species described by them.

The conchifera of the carboniferous system admitted in the preceding lists amount to 112.

Plagymyona 25, mesomyona 17, brachiopoda 70. Of these 3 plagymyonous, 7 mesomyonous, and 31 brachiopodous, are said to be also found in the slate system. On this subject the remarks which follow the enumeration of the conchifera of the slate system may be referred to. Mesomyonous bivalves have now become more numerous, and the enormous preponderance of brachiopoda over the other orders of bivalves is reduced from 6 to 1 to about 2 to 1.

Of these 112 species, 5 are generally allowed to be fluviatile or lacustrine; and their number, if augmented by the yet undescribed species in England, may very

probably amount to 10. Nearly all the marine tribes occur in the limestone group below the coal measures; all the fresh-water species lie in the coal measures; but there is one thin layer of marine shells extensively spread in Yorkshire, in the midst of the coal measures, above certain fresh-water layers and below several others. No fresh-water shell lies in this bed. Hence the series of operations by which that coal field has been formed evidently includes one period of marine, and two of fluviatile or lacustrine action, subsequent to the general and long-continued action of the sea, which deposited the mountain or carboniferous limestone. There is no disturbance of strata nor any thing to indicate local movement during the deposition of the coal, and it is presumed that the alternation of marine and fresh-water deposits, here certainly proved, was occasioned by causes acting at a distance. An additional memoir has been promised on this subject. (See p. 590.)

## MOLLUSCA

Family	Name.	British Localities	Foreign Localities
Gasteropoda {	Pileopsis* vetusta .....	Near Clithero.	
Holostomata {	tubifer .....	Ditto.	
	some other species .....	Ditto.	
	Patchias several species .....	Ditto.	
	primigena, Schl. ....		Ratingen.
	Planorbis, Phil. ....	In coal measures, Yorkshire.	
	Planorbis equalis .....	Kendal.	
	Ampullaria nobilis .....	Queen's County, Ireland	
	helicoidea .....	Ditto.	
	undescribed .....	Clithero, Westmoreland	
	Melania *constricta .....	Buxton, Tideswell.	
	Nerita striata .....	Clithero, Arran.	
	*spirata .....	Bristol, Derbyshire.	
	other species .....	Clithero, Northumberland.	
	Natica elongata, Han. ....		Ditto.
	Gastardota .....		Ditto.
	globosa .....		Visé.
	patula .....		Ratingen.
	undescribed species .....	Clithero, Northumberland.	
	Pleurotomaria {		
	Helix, Sow {	Derbyshire, Yorkshire. ....	Visé.
	striata .....	Derbyshire .....	Ditto.
	several undescribed species	Near Clithero.	
	Cirrus* acutus .....	Ditto, Derbyshire .....	Namur.
	rotundatus .....	Ditto.	
	several undescribed species	Ditto.	
	Euomphalus nodosus .....	Derbyshire .....	Ratingen.

Geology. Ch. II.	Family.	Name.	British Localities.	Foreign Localities.
	Gasteropoda } Holostomata }	Euomphalus angulosus.		
		*catillus .....	Derbyshire, Yorkshire .....	Ratingen.
		delphinularis, Hæn. ....		Ditto.
		pentangulatus .....	Ditto, ditto .....	Ditto, Namur.
		tuberculatus, F. ....	West Lothian.	
		coronatus .....		Visé, Ratingen.
		rotundatus .....		Ditto ditto.
		other undescribed species ..	Near Clithero .....	Visé.
	Turbo	*tiara .....	Ditto.	
		heliciniformis .....		Ratingen.
		undescribed species .....	Northumberland.	
	Trochus	cingulatus, G. ....		Ditto.
		scalaris, G. ....	Several undescribed species at Clithero.	Ditto.
		alutaceus .....		Visé.
		catenulatus, G. ....		Ditto.
		tenuatus .....		Ratingen.
	Turnitella	angulata .....		Ditto.
		Urii, F. ....	Rutherglen.	
		elongata, F. ....	Ditto.	
		spinata, G. ....		Ditto.
		angustata, G. ....	Several undescribed species	Ditto.
		conoides, G. ....		Ditto.
		tenuis, G. ....		Ditto.
		acuminata, G. ....		Ditto.
	Phasianella	auricularis .....		Ditto.
		striata .....		Ditto.
Gasteropoda } Solenostomata }		Buccinum acutum .....	Queen's County, Ireland	
		undescribed species .....	Near Clithero.	
		Rostellaria ? .....	Ditto.	

This catalogue of gasteropodous mollusca is very incomplete. At least as many more species, most of which are in the possession of Mr W. Gilbertson of Clithero, remain to be added to it from the limestone of Yorkshire alone. Several others were collected by the late Mr. Miller near Bristol, and by the Rev. C. V. Harcourt in Northumberland.

## MOLLUSCA.

Family	Name	British Localities.	Foreign Localities.
Cephalopoda } Monothalamia }	Bellerophon *hulcus .....	Derbyshire, Yorkshire .....	Visé, Ratingen.
	*costatus .....	Derbyshire, Dublin .....	Ditto, ditto.
	*tenuitascia .....	Settle, Kendal, Ireland .....	Ratingen, Visé.
	*apertus .....	Settle, Ireland.	
	*constrictus .....	Kendal.	
	Urii, F. ....	Rutherglen.	
	decussatus, F. ....	Lamhithgow.	
	striatus, F. ....	Ditto.	
	depressus, Montf. ....		Ratingen.
	vasculosus, Montf. ....		Namur.
	undescribed .....	Yorkshire, Westmoreland.	
	umbriatus, G. ....		Ratingen Visé.
	sulcatus, G. ....		Ratingen.
Cephalopoda } Polythalamia }	Orthocera giganteum .....	Clooseburn.	
	cordiforme ..?	Ditto .....	Visé
	undulatum .....	Clithero, Settle.	
	Bryum .....	Ashford, Clithero.	
	fusiforme .....	Clithero, Queen's County.	
	cinctum .....	Clithero	
	Gesneri, Mart .....	Ashford.	
	lance, F. ....	Lamhithgow.	
	pyramidale, F. ....	Ditto.	
	cylindraceum, F. ....	Lavingstone.	
	annulare, F. ....	Lamhithgow.	
	rugosum, F. ....	Ditto.	
	angulare, F. ....	Ditto.	
	attenuatum, F. ....	Lavingstone.	
	sulcatum, F. ....	Ditto.	
	undatum, F. ....	Ditto.	
	Steinhaueri .....	Halifax, Yorkshire.	
	Conularia sulcata .....	Bristol, Rutherglen, Coalbrook Dale	
	teres .....	Scotland.	
	Nautilus complanatus .....	Isle of Man.	
	Hendlowi .....	Dittry	
	*globatus .....	Yorkshire .....	Ratingen.
	multicarinatus .....	Ditto	
	bilobatus .....	Clooseburn, Yorkshire.	
	pentagonus .....	Clooseburn, Kendal.	
	tuberculatus .....	Clooseburn.	
	dineus .....	Kendal.	

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	Cephalopoda	<i>Nautilus Woodwardii</i> .....	Winstar, Yorkshire.	
	Polythalamia	<i>sulcatus</i> .....	Castleton.	
		<i>ingens</i> .....	Ashford.	
		<i>biangulatus</i> .....	Bristol, Yorkshire.	
		<i>*cariniferus</i> .....	Yorkshire.	
		<i>excavatus</i> , F. ....	Limerick.	
		<i>magnatus</i> , F. ....	Bathgate.	
		<i>quadratus</i> , F. ....	West Lothian.	
		<i>Lidii</i> .....	Ashford, Ireland.	
		undescribed .....	Sheffield.	
		<i>Ammonites striatus</i> .....	Buxton, Castleton, Craven.	
		<i>sphaericus</i> .....	Milldale, Craven.	Liege, Werden.
		<i>Listeri</i> .....	Middleton, &c. Sheffield	Liege.
		undescribed .....	Eton.	
		several new species .....	Yorkshire and Lancashire.	
		<i>carbonarius</i> , G. ....		Ditto, Werden, Wettin.
		<i>Henslowi</i> .....	Isle of Man, Yorkshire.	

The mollusca of the carboniferous epoch are but imperfectly known, notwithstanding the labours of Sowerby, Fleming, and others, and we can hardly venture to expect that the numerical relations of even the leading divisions will remain unchanged, when the numerous additional species shall have been described. The present ratios are, gasteropoda about 55, cephalopoda 57, of which 16 are monothalamic, which are not very

different from the proportions in the slate system. Above this epoch, monothalamic cephalopoda disappear wholly until new tribes of them are recognised above the chalk. It is proper to mention that the situation which we assign to bellerophon among the cephalopoda is not admitted by all Naturalists. The names of the mollusca are from Sowerby, except where other authors are quoted.

Family.	Name.	British Localities	Foreign Localities.
Crustacea	<i>Asaphus Dahmanni</i> , G. ....		Ratingen
	<i>Calymene Derbionensis</i> , Mart. ....	Ashford.	
	<i>lunatus</i> , D. ....	Ironst. Mansfield, Notts.	
	<i>Cancer a claw</i> .....	Northumberland.	
Amudosa	<i>Serpula compressa</i> .....	Lothian.	
Fishes	<i>Ichthyodonta</i> .....	(Mr. Ludlow,) Bristol, &c.	
	<i>Palates</i> .....	Bristol, Westmoreland, Northumberland.	
	<i>Scales</i> .....	Canthness.	
	<i>Dipterus brachypogon</i> .....	Ditto.	
	<i>macropogon</i> .....	Ditto.	
	<i>Valenciensis</i> .....	Ditto.	
	<i>macrolepidotus</i> .....	Ditto.	
	<i>Osteolepis macrolepidotus</i> .....	Ditto.	
	<i>microlepidotus</i> .....	Ditto.	
	<i>Saurian vertebra</i> .....	"In gravel of limestone." Northumberland. (C. V. Harcourt.)	

#### GENERAL SUMMARY.

569 species of organic remains, of which 62 are stated to be found in the slate system below, and 8 in the magnesian limestone above.

Plants	274 species	Terrestrial, of which (omitting sigillaria) about 190 are cryptogamous and 40 phanerogamous.
Polyparia	30	Cellulifera 17, lamellifera 13.
Radiaria	26	Amongst these echinoda distinctly appear.
Conchifera	112	Plagymyona 25, mesomyona 17, brachio-poda 70.
Mollusca	112	Gasteropoda 55, cephalopoda 57.
Annulosa	1	
Crustacea	4	
Fishes	10	
Saurian	—	

569

#### Saliferous System.

It has been shown that the consolidated deposit of coal was subject to the effects of a very general eruption of igneous agency from beneath, and that in this manner the whole arrangement of those deposits was altered, and many parts of the bed of the sea uplifted to form dry land. In the large but very irregular area left between these islands of carboniferous strata, the sea

began to deposit limestones commonly charged with magnesia, sandstones remarkably coloured with red oxide of iron, and clays and marls of red, blue, and white colours; the whole series being, in general, far from rich in organic remains, seldom traversed by metallic veins, and not so much dislocated by faults as the older strata. Salt in beds or nodules, accompanied by gypsum, lies very commonly in this series of rocks, and hence it may be termed emphatically the saliferous system. Generally, its stratification is wholly unconformed to that of the subjacent coal measures, or whose elevated edges, breaks, and dykes, its planes rest level and undisturbed.

In the composition of this group we find traces of all the various operations of the sea; limestones crystallized, compact, brecciated, conglomerated, and earthy, full of magnesia, or containing carbonate of lime with little or no admixture. Locally rich in organic remains, but generally devoid of them: sandstones coloured red, blue, or white, in stripes and spots, fine grained, coarse grained, or full of innumerable pebbles, derived from primary and secondary rocks; clays and marls of many various hues; both the sandstones and clays locally productive of the remains of saurians, shells, and plants, but over large tracts wholly destitute of them. These

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organic remains are partly analogous to those of the carboniferous system, and partly to those which occur in the more recent oolites, and the whole formation, though so peculiar in character as to be readily, and indeed unavoidably, separated from both those systems, offers by many resemblances, besides its intermediate position, a natural transition from the one to the other.

This may perhaps appear to those who only have seen the saliferous system in England, where its total unconformity to the coal, and dissimilitude to the strata above and below, are matter of notoriety, a proposition deserving further explanation. The facts on which it rests will be found in the following pages, and they will give reason to presume that when we have assembled data sufficient for satisfactory induction, those *interruptions in the series* which appear to indicate great and sudden revolutions will be proved to be merely local, and to arise from the *omission* in certain situations of strata elsewhere deposited in great force.

It has already been stated that in the Island of Arran the primary strata are succeeded by a very thick series of red and white sandstones and conglomerates, and that coal measures and carboniferous limestone lie included in this mass like subordinate or local formations. The conglomerates below the limestone represent the old red sandstone, and the upper sandstones above the coal represent the new red sandstone formation, and it might be possible to include the whole of the carboniferous and saliferous systems of rocks together under the name of red sandstone formation. This is the view of the subject taken by Von Hoffman, from observations in the North Western part of Germany, where in a mass three or four thousand feet thick of red and white sandstones, lie the diminished strata of coal.

Nevertheless, these cases, though affording very instructive inferences as to the continuity of the operations of Nature, are not to be taken as general types of the series of strata, and throughout the greater part of the British Islands, as well as in the South-East of France and in Germany, the saliferous red sandstone series, with its accompanying limestones and marls, is a distinct system of strata, characterised by peculiar features of mineral composition, and organic contents, and marked by a general aspect of physical geography.

England.

In England, supposing all the parts of the saliferous system of rocks present in one section, we should have, reposing unconformably on the coal strata, the following classification, beginning from above.

- |  |   |
|--|---|
| <p>1. Series of coloured marls . . . . .</p> <p>3. Variegated red and white sandstone . . . . .<br/>(Pencilite of Conybeare.)</p> <p>2. Magnesian limestone.</p> | <p>Purple coloured marls below the bas.<br/>Alternations of red and bluish white marls, with layers and nodules of gypsum.<br/>Thin layers of argillo-calcareous stone.<br/>Red and bluish marls with gypsum and beds of rock salt.<br/>Red and white sandstone, mostly fine grained, and often impregnated with salt.<br/>Red conglomerate, full of pebbles of older rocks.<br/>Red and white marls.<br/>Thin bedded compact limestone, with very little magnesia and few organic remains.<br/>Red and white marls and gypsum.<br/>White, yellow, or reddish magnesian limestone in thick beds, crystallized, compact, or earthy, often full of sparry cavities, and containing marine organic remains.<br/>Marl slate, in thin layers, occasionally enclosing fishes.</p> |
|--|---|

1. Yellow or purple sand and sandstone and marl . . . . .

An extremely variable series of sandstones, sands, and clays, of various colours, irregular thickness, and much local diversity of character.

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### Range of the Saliferous System in England.

Of the beds included in this arrangement, the calcareous strata are perhaps the least extensive, yet, as usually happens, they are most regular and continuous in their ranges, and most consistent in characters, and afford the best data for the classification of the others. By looking at Mr. Smith's, or Mr. Greenough's Geological Map of England, the extent of the range of magnesian limestone may be observed from the North side of the Tyne uninterruptedly to the Tees, between which river and a place called Thornton Watlas, it is known only in a few points, though probably it exists continuously beneath the superficial accumulations of gravel. From this point to Bilborough, near Nottingham, its course is uninterrupted.

Below it, in a narrow, irregularly parallel tract to the West, reposing on all the members of the coal formation indiscriminately, runs the lower series of sandstones and marls; above on the East through Yorkshire and Nottinghamshire ranges the conglomerate red sandstone, and upon this lies, through Durham, Yorkshire, and Nottinghamshire, the series of upper coloured marls and gypsum.

On the Western side of the summit ridge of the North of England, the vale of the Eden is filled by the new red sandstone formation, consisting principally of coarse or fine-grained red sandstone, and red marl above, with, in one place, a remarkable series of conglomerate, or rather brecciated beds at the bottom, and in another a distinct deposit of magnesian limestone. The former are seen at Kirby Stephen in the angle between two lines of dislocation, and afford a very instructive point of comparison with an analogous deposit in Somersetshire, known by the name of millstone. It has a basis of red sandstone almost entirely filled with angular fragments of different sizes of the neighbouring limestone strata, it is disposed in vast unequal beds, with large distant joints almost invariably ranging North and South, lies with a dip to the East between the lines of two dislocations of the carboniferous limestones, to the violence accompanying which its own production was probably owing. It is not in general magnesian, yet some yellow beds probably contain that substance, and thus we are led to refer its production to the date of the lower parts of the magnesian limestone.

No further trace of beds analogous to the magnesian series of Yorkshire and Durham occurs, in the Westward extension of the new red sandstone group round the Cumbrian mountains, till we reach Whitehaven, where magnesian limestone and conglomerate, lying in red sandstone, are sunk through in the coal pits, and seen in the high cliffs against the sea towards St. Bee's Head. From Professor Sedgwick's examination of this district we learn that the section here presented is more closely similar to that of Yorkshire than was previously supposed, and that the following groups are uniformly laid upon the coal system.

- |  |   |
|--|---|
| <p>3.</p> <p>2. Magnesian limestone.</p> | <p>Variegated red sandstone of St. Bee's Head.<br/>Red marl and gypsum.<br/>Magnesian limestone, sometimes replaced by or alternating with magnesian conglomerate.<br/>Magnesian conglomerates, analogous to those in the vale of Eden, and various parts of Yorkshire.</p> |
|--|---|

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1.

Coarse reddish sandstone of great thickness on the whole unconformed to the coal measures, but also in part unconformed to the rocks above, which lie in its hollows.

Remarks on certain Members of the Saliferous System in England.

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Variegated sandstones and clays.

Midland Counties.

In their Northward extension beyond the Solway Frith to Dumfries-shire and Galway, the red sandstone strata do not exhibit any traces of magnesian limestone.

Beyond the Southern termination of that rock, near Nottingham, the variegated red sandstones and coloured marls spread themselves over the whole area between Leicester, Warwick, and Worcester, on the one side, and Shrewsbury, Chester, Liverpool, on the other, and extend Northwards to Manchester, Leek, and Ashbourn. Yet in all this immense area, except at Ardwick, near Manchester, and near Shrewsbury, we nowhere find any deposits analogous to the magnesian limestone. At Ardwick a limestone is dug containing, as we have been informed by Dr. Henry, magnesia; and we may believe that its geological situation is similar. In this neighbourhood also, as at Worsley collieries, we appear to recognise the lower red sandstone of Yorkshire, in several places overlying the coal beds, and it is probable that further examination may extend these points of agreement. Near Shrewsbury, likewise, the coal strata are preceded by what appears to correspond to the lower red sandstone, and upon this lies a porphyritic magnesian conglomerate.

South of England.

South of Worcester the variegated sandstones and marls, the latter predominating, pass down the Vale of the Severn, fill up the winding intervals of the dislocated carboniferous limestone, partly cover the coal basins of Somersetshire, spread in the vales of the Parret and the Exe, and reach the sea at Exmouth.

The only parts of this extensive range where magnesian rocks appear distinctly, is amongst the limestone and coal tracts of Somersetshire and South Gloucestershire. Along the sides of Mendip magnesian conglomerates of considerable extent separate the limestone from the red sandstone, and produce the ores of zinc; a similar deposit, in similar relation to the older limestone, appears along the Avon below Clifton, and at Radstock and other places it is pierced in the collieries, at or near the bottom of the red sandstone, and receives the name of millstone. Conglomerates of a very singular, even porphyritic, character occur near Exeter, in the lower part of the variegated sandstone and marls, and from a general review of the whole subject, Professor Sedgwick classes the conglomerates of Exeter, Somersetshire, and Shropshire, with the lower or conglomerate portion of the magnesian limestone of the North of England. Some doubt may perhaps yet remain as to the propriety of including in this system the red conglomerate of Exeter, which is by Mr. De la Beche ranked with the rothetodteliegende, but in the other points the inference appears certain.

From this view of the subject which we fully adopt, it would appear that the difference of the saliferous system, in different parts of England, arises rather from the limited continuity of the beds, than from any great variation in their quality or relations. The series of the saliferous system is perhaps nowhere more complete than in the interval between the Wharfe and the Dun, yet even here several beds are deficient. The marl slate and conglomerate limestones are better studied in Durham, the upper coloured marls are better exhibited in Nottinghamshire, and the beds of salt must be examined in Cheshire.

The variegated sandstones and coloured clays of the British series, being destitute of organic remains, and subject to no very remarkable changes of character, what has been said will suffice for the purpose of comparison between them and the analogous deposits in other parts of Europe. But before we proceed to this comparison, it will be useful to describe more particularly the general characters of the terrace of magnesian limestone, and its associated strata, which occupies so remarkable a range in the North of England. The table already given will explain the relation of the several members of this group, and we shall at present confine our attention to the calcareous portions. The most ample details on every point will be found in Professor Sedgwick's Paper in the *Geological Transactions*.

Immediately above the lower red sandstone in the excavation for the Stockton Rail-road, were found in ascending order, (1.) thirty feet of light-coloured, silicious sandstone in thin beds, alternating at the top with blue calcareous slate. (2.) Nine feet of yellow calcareous shale and marl slate, some of the beds incoherent and sandy. In this marl slate about two feet above the sandstone were found many impressions of vegetables (*ferus*) and fishes of the genus *paleothrissum*. The higher and more compact beds also contained *productæ*, *spiriferæ*, and *terebratulæ*. The shales or marls of this series are sometimes highly bituminous. (3.) Twenty feet of thin calcareous beds with marly partings.

Marl slates.

These slaty marls and limestones have a very irregular extent even in Durham, and are imperfectly traceable in Yorkshire. They are perhaps best exhibited at Garforth Cliff, on the road from Leeds to Selby, where they are full of *axinus obscurus*, and contain a species of *producta* not yet described. Deposits somewhat analogous are described by Professor Sedgwick near Bolsover. Little or no magnesia is found in this part of the series.

The yellow magnesian limestone whose extreme thickness between the Aire and the Dun certainly exceeds 300 feet, exhibits the most astonishing diversity of mechanical structure, without a corresponding diversity of chemical composition or definite geological divisions. Several varieties yield upon analysis carbonate of magnesia and carbonate of lime, in the simple proportion of atom to atom, (for example, the building stone of Huddleston and Warmsworth,) and in almost all the proportion of magnesia is large. In the Southern part of its range, the structure of the rock is generally crystalline, and the crystals (rhomboids) being small, and often tinged of a reddish or yellow colour, the whole might be easily mistaken for sandstone. On the contrary, in the Northern part of its range, a concretionary structure is often observed, and thus globular masses of carbonate of lime of various magnitude compose beds of stone or lie loose amongst a quantity of yellow, powdery, calcareo-magnesian carbonate. But the variety of the appearances presented by this kind of structure is so great, that on entering a quarry near Sunderland we are struck by the organic aspect of the whole escarpment, as if it had been a reef of coral. On the coast of Durham beds of this structure appear associated with masses of brecciated limestone, but very irregularly, and under circumstances not easily explained, without sup-

Yellow magnesian limestone.

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posing the deposits to have been subject to repeated local and violent disturbance.

Certain beds of this rock in Yorkshire and Derbyshire are very compact; in Durham some are composed of numerous thin, incoherent layers. In several places North of the Dun and near Tadcaster oolitic portions are distinguishable.

But by far the most plentiful of all the varieties of this changeable rock, especially to the North of the river Wharfe, is a loose earthy mass of indistinct beds, with hollow geodes of crystallized carbonate of lime, and numerous veins or strings of the same substance, dividing the rock into angular cells, and helping to hold it together. This character of crystallized cavities and sparry strings is very common to the whole formation, and we occasionally find oxydulated iron, sulphate of strontian, or sulphate of barytes in these cavities. In the quarries at Weldon occur layers of silicious nodules, analogous to the chert lumps in limestone, in oolite, and green sand, and to the flints in chalk. Veins of sulphate of barytes cross the magnesian limestone in several places near Ferrybridge, and near Wetherby. Galena occurs in it at Mansfield and at Warmsworth near Doncaster in small veins, and in other places in detached crystals, as does also sulphuret of zinc; carbonate of copper lines some joints of the rock at Newton Kyme near Tadcaster, at Warmsworth, and at Farnham near Knaresborough; muriate of soda has been obtained by Mr. Holmes from the red beds of Mansfield, and a solitary lump of red rock salt was found in connection with it near Pontefract.

Organic remains of retepora, crinoida, brachiopodous bivalves, and other shells of mollusca, occur in this rock, in by far the greatest abundance near Sunderland in Durham; they are much less plentiful in the upper parts of the rock in Yorkshire between the Dun and the Wharfe; and only a few species obscurely show themselves in Derbyshire and Nottinghamshire. There is a great analogy between the organic remains in the magnesian limestone of Durham, and those of the older carboniferous limestone, and it especially deserves attention that in this rock the genus *producta* is seen for the last time as we ascend the series of strata, while no ammonite has yet been found in it.

Above the yellow magnesian limestone is a series of gypseous red and white marls, fifty feet thick or more, and this is surmounted by the upper laminated limestone.

Upper laminated limestone.

This rock is not coextensive with the yellow limestone, but has a more limited range, scarcely extending beyond the boundaries of Yorkshire. It is most fully developed in the tract between Tadcaster and Tickhill, and may be examined advantageously at Brotherton and Knottingley, where enormous quantities of it are burned annually to lime for agricultural purposes.

It here reaches to about fifteen yards in thickness, and is composed of a vast number of small irregular layers, separated more or less by partings of marl, and obscurely united into uneven and often undulated beds. The stone is nearly devoid of magnesia, its substance is usually compact, so as even to fit it imperfectly for the purpose of lithography; it is remarkably full of dry cracks, which have dendritical faces, and small cavities lined with crystallized carbonate of lime appear in the thicker layers. The thickness of the layers increases suddenly, or the beds become more consolidated toward the bottom, and in this part the crystallized cavities become more numerous and larger, the stone is less com-

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compact, holds more magnesia, and is of no value for lime. The prevalent colour of the stone is a smoke-grey, which is often disposed in spots or stripes, and the separating marls are generally light grey, but often purplish, and further South reddish.

Organic remains occur but very rarely, and in the lower beds only. They are very imperfect in general, but appear to be of the same species as others from the yellow limestones of the same vicinity.

Further North, at Nosterfield, these beds change their aspect considerably, so as to resemble closely some kinds of carboniferous limestone, a resemblance increased by the presence of *productæ*, and the occurrence of galena. About Doncaster this rock assumes a redder aspect, and contains some beds full of magnesia. It is then said to be a *hot lime*, and like the product of the yellow limestone, is injurious if laid on the land in large quantity.

The stony beds mentioned in the general classification of the saliferous system occur at a few points about Gainsborough in Lincolnshire, and Tuxford in Nottinghamshire, as we learn from Mr. Smith, who distinguishes it by the provincial title of *waterstone*; and perhaps the hard white beds at Newnham in Gloucestershire may be referred to the same rock. Its course remains to be further traced, and deserves attention as perhaps affording a term of comparison with the magnesian layers described by M. Elie de Beaumont in the variegated marls of Alsace.

The following abstract of Mr. Holland's Paper in the *Rock salt. Geological Transactions*, vol. i., will convey a good notion of the situation and mode of deposition of the rock salt in Cheshire.

Cheshire unites with the Southern part of Lancashire and the Northern part of Shropshire into a great plain, fifty miles long from North to South, and about twenty-five or thirty wide. It is bounded on the East and on the West, and interruptedly on the South, by carboniferous ranges of hills; and the internal area is divided by two ranges of rising ground into three minor plains, which serve to conduct the Dee, the Weaver, and the Mersey to the Irish Channel. The range of Delamere Forest on the West, and an undulated tract ranging nearly Westward to Halton and Runcorn, define the drainage of the Weaver, and include the most abundant sources of salt. Scarcely any rock salt is found except in this limited tract. On approaching the estuary of the Mersey, the ridges which bound the plain approach one another at two points, and suggest the idea of the included plain having been once a lake.

Character of the country.

The salt which lies under this plain is found to thicken, at least partially, toward the contraction of the valley; it does not, however, lie beneath the whole surface of the low ground, nor indeed in one connected mass, but occurs in detached masses of limited area. The rock salt of Northwich ranges North-East and South-West, and its breadth is about three-quarters of a mile. The upper bed is thickest on the North-West, and thins off toward the South-East.

Two beds of salt at Northwich, &c.	Three beds at Lawton.
Rock salt . . . 20 to 30 yards,	42 yards marl, &c.
Parting of } 11 yards.	4 feet salt.
marls, &c. }	10 yards marl, &c.
Rock salt 35 yards known.	12 feet salt.
	15 yards marl, &c.
	24 yards salt.

The upper bed has been worked through only at North-



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wich and Lawton. No marine exuvæ occur over the salt, or in any way associated with it. The purest part of the salt in the upper bed is about three or four yards above the bottom of the bed, and about four feet in thickness; the purest part of the lower bed is twenty or twenty-five yards deep in it, and five or six yards thick, below which the salt becomes earthy as above. This is the part worked. The salt is not stratified, but divided into vertical prisms of various polyhedral forms, and different magnitudes, sometimes a yard or more in diameter. The sides of these prisms consist of pure white salt. Gypsum abounds in the marls associated with the salt, the most abundant variety being the fibrous kind.

Mr. Holland supposes that what is now the salt field was once a salt-water lake, separated from the sea by a natural dam; that the evaporation of the water caused the precipitation of the salt, and that it was afterwards covered with the laminated marls. To account for so much salt, he imagines that the sea might often overpass the dam.

Perhaps we may say that there was here a lake of salt water, of which the deposit went on gradually, and that at intervals violent floods filling it with muddy matter, this was precipitated with gypsum, but without salt, but that afterwards the water again subsiding, salt fell as before. If the floods came in from the sea, this might explain the correspondence in character of these gypsaceous marls, and those which elsewhere belong to the Keuper era.

Section.	No.	Yds.	ft.	in.	
Northwich.	1	5	0	0	Calcareous marl.
	2	*1	1	6	Indurated red clay.
	3	2	1	0	*Indurated blue clay.
	4	1	2	0	Argillaceous marl.
	5	0	1	0	*Indurated blue clay.
	6	*1	1	0	Red clay with sulphate of lime irregularly intersecting it.
	7	1	1	0	*Indurated blue and brown clay, with grains of sulphate of lime interspersed.
	8	4	0	0	Indurated brown clay, with much sulphate of lime crystallized in irregular masses.
	9	1	1	6	*Indurated blue clay laminated with sulphate of lime.
	10	1	1	0	Argillaceous marl.
	11	1	0	0	Indurated brown clay laminated with sulphate of lime.
	12	1	0	0	*Indurated blue clay laminated with sulphate of lime.
	13	*4	0	0	*Indurated red and blue clay.
	14	4	0	0	Indurated brown clay, with sand and sulphate of lime irregularly interspersed through it. The fresh water (360 gallons per minute) finds its way through holes in this stratum, and has its level at 16 yards from the surface.
	15	1	2	0	Argillaceous marl.
	16	1	0	9	*Indurated blue clay with sand and grains of sulphate of lime.
	17	5	0	0	Indurated brown clay with a little sulphate of lime.
	18	0	1	6	*Indurated blue clay with grains of sulphate of lime.
	19	2	1	0	Indurated brown clay with sulphate of lime.
	20	25	0	0	ROCK SALT.
	21	10	1	6	Layers of indurated clay with veins of rock salt (occasioned by water filtering) running through them.
	22	76	1	9	
	22	36	0	0	ROCK SALT sunk into 35 or 36 yards.

English Geologists have, till lately, commonly believed that rock salt was the peculiar production of the red marl and red sandstone; but the mines of Wietzka

are in green sand, those in the Salzburg Alps in limestone of the oolitic period.

By far the larger proportion of ordinary springs, from whatever strata they issue, yield muriate of soda, sometimes in very large quantity, and it is important to know that bromine and iodine, which are stated to be always existent in the actual sea water, very generally accompany the muriatic salts in common springs. This is most remarkably the case with bromine. (See *Phil. Trans.* 1830.) The rock salt of Cheshire is perhaps entirely devoid of bromine and iodine, though the brine springs of the same district are found to contain both. The reason of this may be that the hydrobromic and hydriodic salts have not the same ratio of solubility as the muriate of soda.

#### Saliferous System of Europe.

We are now at liberty to consider the characters of the saliferous system as they appear in the other parts of Europe, which have been accurately examined by Geologists. This comparison is much facilitated by the mutual understanding now so general between English and foreign observers, and the subject is made familiar to our countrymen by the published inferences of Sedgwick, Voltz, and De Beaumont. The Rhine in its Northward course from Basle divides into two unequal parts an immense area, in which the saliferous system mantles round the primary ranges of the Vosges, Schwartzwald, Odenwald, Spessart, Thuringerwald, and Harz mountains. The natural boundaries of this irregular area, are, on the West, South, and South-East, the French, Swiss, Swabian, and Bavarian ranges of Jura limestone; on the North-West, the slate formation of the Ardennes, Nassau, and Westphalia; on the North the tertiary plains of Northern Germany. Over all this immense tract, the saliferous system contains a calcareous stratum at present unknown in Britain, called the Muschelkalk, a rock which, in some of its external characters, particularly its smoke-grey colour, and association with marls, bears a considerable analogy to the upper layers of the magnesian limestone formation of England, but by the occasional abundance and general character of its organic remains is strongly assimilated to our lias.

In several districts different portions of the sandstones and marls contain organic remains both animal and vegetable, which are entirely distinct from those yet known to belong to the older formations, but greatly resembling those of the lias and oolites, so that the foreign localities of the new red sandstone series supply us with those links in the chain of general Geological facts which are wanting in Britain, and for want of which English Geologists have been accustomed to view in too absolute a light the distinction between the carboniferous and the oolitic formations. On the other hand, in the greater part of the saliferous system on either side of the Rhine, beds corresponding to the magnesian limestone of England are entirely unknown. It is chiefly along the line of the South-Western face of the Thuringerwald, prolonged to the North-West as far as Münden, in the drainage of the Weser, along the Southern and Eastern borders of the Harz, and on the North-West side of the slate formation connected with the Erzgebirge, in the drainage of the Elster, that the zechstein and rauchwäcke represent on a greater scale the yellow magnesian and upper laminated limestone of the North of England.

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Salt which, as above explained, occurs in England in beds only in the variegated marls, is found in one or other side of the Rhine in every bed of the system.

From these remarks it is evident that there is a great general resemblance between the characters of the saliferous formation as it exists in Germany, France, and England; but to make the differences equally apparent, it will only be necessary to fix our attention upon two districts in particular, *viz.*, the Vosges mountains, which range to the North-East parallel to the Rhine, and the district in the North-East of Upper Germany, adjoining the Thuringerwald and the Harz mountains.

The general succession of strata in the saliferous system round the Vosges mountains may be well seen on the road from Metz to Strasburgh; and the minutest details of the beds have been ascertained by those eminent Geologists, Voltz and Elie de Beaumont; to the former of whom we owe the discovery of most of the vegetable fossil of these rocks, and to the latter a valuable discussion of the relations of the formations.

Between the bottom of the oolitic system and the top of the saliferous system occurs, about Luxembourg especially, a peculiar sandstone, which has hardly been distinctly recognised in any other situation. Below this, in descending order, is the following series of strata.

Section of  
the Vosges.

4 Variegated marls, Keuper of Germany, *marnes irisées* of France.—Red, pale blue, greenish, &c., with gypsum occasionally interstratified, especially near the top, with beds of sandstone of different kinds, containing plants of the families calamites, equisetaceæ, lycopodiaceæ, coniferae, cyadeæ, &c., univalve and bivalve shells, remains of saurians and chelonida.

In these coloured marls, above the middle, lies a regular bed (six to ten feet thick) of extremely compact magnesian, yellow limestone, without fossils, and under it, in several places, black schistose marls; in this part, also, gypsum is especially abundant. In several situations, thin bands of reddish limestone occur, alternating with anhydrite.

3. Muschelkalk.—Limestone, generally compact, of a light grey or smoky colour, with partings of marl, containing peculiar encrinurites, with ammonites, plagiostomata, and other shells analogous to those of the oolitic system, and remains of reptiles. Near Luxembourg it is very thin, and may easily be mistaken for lias; near Saverne it is much thicker, and more characteristic. At Bourlgonne les Bains it is a true magnesian limestone. As before observed, it does not exist in England.

2. Variegated red sandstone, (*Bunter sandstein* of Germany, *grès bigarré* of France)—Extremely similar to the new red sandstone of England. This also contains, locally, abundance of organic remains, both animal and vegetable.

1. The strata above named rest, in some places unconformably, upon a vast thickness of red sandstone, in general much coarser, and more like a conglomerate than the variegated red sandstone; the pebbles of quartz, which it contains in abundance, appearing to be derived from the ruins of portions of the primary rocks of the range of the Vosges. The magnificent precipices down which the road descends to Saverne, among grahd old woods and torrents, are formed by this rock, and the resemblance which it bears to the old red sandstone conglomerate of Monmouthshire, is such as to bias the English Geologist strongly in favour of that approxi-

mation. In other cases, and especially in hand specimens, this rock appears to resemble the coarse red sandstone of Dumfries-shire and of Penrith Beacon, and as these rocks certainly overlie the carboniferous series, this comparison may, perhaps, be exact. The Northern part of the Vosges mountains being wholly composed of these grit rocks, and coal beds being found at many points in the same vicinity, the incumbency of the red sandstone upon the coal is satisfactorily proved.

The lower part of this thick arenaceous group, which rests upon the coal series, is usually of a friable and fragmentary nature, containing admixtures of porphyritic masses, which strongly assimilate it to the red sandstone conglomerate of Exeter, and the red sandstone, expressively so called, of the North of Germany. The upper part, also, gradually becomes finer grained, and more like the ordinary variegated red sandstone; but as in several places this latter rock rests unconformably upon the other, we are justified in adopting the opinion of Voltz and De Beaumont, that it is a portion of the red sandstone series, almost peculiar to the Vosges mountains, and may, therefore, be characterised as the *grès des Vosges*.

The North-East of Germany gives us the following section of the saliferous system. North-East  
of Ger-  
many.

5. Variegated marls, (*Keuper, marnes irisées*) with gypsum, and the usual characters of the strata.

4. The muschelkalk, much as it occurs about the Vosges. It admits of subdivision into two, or, perhaps, three parts, which, according to Hoffman, may be distinguished by their respective types of organic remains.

3. Variegated sandstone. (*Bunter sandstein, grès bigarré.*)

2. Zechstein, or magnesian limestone formation, consisting of the following members:—

a. Rauchwacke, asche, stinkstein, &c. with gypsum.  
Coloured marls.

b. Kupferschiefer and zechstein.

1. Lower red sandstone, (*Rothetodteliegende, grès rouge*), which is often associated with porphyritic masses like the red sandstone of Exeter.

The following Table will show the relations of the three tracts.

England.	France.	Germany.
4. Variegated marls.	5. Marnes irisées.	5. Keuper.
	4. Muschelkalk.	4. Muschelkalk.
3. Variegated sandstone.	3. Grès bigarré.	3. Bunter sandstein.
2. Magnesian limestone.	2. Zechstein.	2. Zechstein.
1. Lower red sandstone.	1. Grès rouge.	1. Rothetodteliegende.

A more minute analysis of the zechstein and magnesian limestone series furnishes the following comparison.

England.	Germany.
Upper laminated limestone.	Stinkstein, Rauchwacke, &c.
Gypsiferous coloured marls.	Coloured marls and gypsum.
Yellow magnesian limestone.	Zechstein.
Marl, slate, and fishes, or limestone with shells.	Kupferschiefer, and fishes of Mansfeld.
Lower red sandstone.	Rothetodteliegende. (Upper part.)
	Coal formation.

And we might by a diagram express the gradual change from one of these types to another, putting the Vosges section between those of England and Germany.

With respect to organic remains it may be sufficient to remark generally that they are found locally in

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abundance in all the members of the saliferous series in Germany and France, while hitherto they have appeared in England confined to the two lowermost groups.

Salt.

It appears that the greater part of the salt beds of Germany occur in the muschelkalk, between Magdeburg and Osnabruck, and in the Valley of the Neckar in Würtemberg. At Vic, Baden, and Lons le Saulnier, salt lies in red marl, along the North side of the Tyrolean alps in red sandstone. (Altenau, Berchtholden,) and it is possible that the abundant salt-works on both sides of the Carpathians in Transylvania and Moldavia may be established on this series. The salt of European Russia (Strangways, in *Geol. Trans.*) is also connected with the new red sandstone; but the geological age of the salt amongst the sands (said to be red) of Persia, in India between the Indus and Chellum, in Africa, New Holland, and North America, is at present a matter of conjecture, though in the Valley of the Mississippi we recognise the characters of a red sandstone deposit. The salt of Cordova, in Spain, and various points along the line of the Pyrenees, appears to lie in green sand; that of the Salzburg alps belongs to alpine limestone of the oolitic area, while in Sicily salt is found in sulphureous tertiary marl, and at Wieliczka it lies in tertiary strata containing a few shells.

*Circumstances attending the Origin of the Saliferous System.*

Its marine  
origin.

From the preceding statement we may confidently decide that the whole of the strata belonging to the saliferous system were deposited in the sea around the previously elevated lines of older rocks. The mechanical aggregates of sandstone, and clays, and marls, do not in general show us those exceedingly fine laminations and indefinitely numerous alternations of different materials which mark the coal deposits, they do not abound in such a multitude of spoils of the land, nor contain extended layers of the reliquiae of fresh water. Had he never known of the local accumulations of fossil plants in the Keuper and variegated sandstones of the Continent of Europe, the English Geologist might have consistently doubted whether inundations from the land had ever disturbed the regular operations of the sea during this period. To explain this irregularity of distribution of terrestrial plants, it may be supposed that inundations from the land happened only in particular places along the margin of that ancient sea, or it may be said that the inundations being general, the growth of plants was limited. With respect to the accumulation of the rocks themselves, equal difference of opinion may be indulged; for if the remarkable absence, from the greater part of the area of the saliferous system, of any marine exuviae in the mechanical aggregates might favour the notion of the materials being wholly derived from the land, yet the mere fact of the extraordinary and connected extent, the remarkable *uniformity of character of these extensive deposits*, even where the more anciently elevated strata round which they were evidently formed are of entirely different nature, and their apparent *independence* of these boundaries of their surface, seem to prove either 1. that the materials were collected by the action of the sea itself; or 2. that when brought into it by other agents, they were for very long times exposed to its equalizing action.

This long action of the waves upon the particles of

the silicious and aluminous rocks and minerals which compose the mechanical aggregates and sedimentary deposits of the saliferous system, is also suggested by the amazing prevalence of the colour of peroxide of iron, which covers as a varnish so many of the particles; and it is confirmed by the discoveries of the organic remains, since these are of such a nature as to prove that during the saliferous period the whole living creation of the carboniferous period came to an end, and was replaced by several peculiar tribes which likewise finished their career and yielded to the more numerous races which fill the oolitic rocks.

The calcareous portion of this system presents us with even more decisive evidence, from its organic remains, of its marine origin, but the circumstances which permitted the accumulation of the magnesian carbonates of lime are in great measure unknown to us. That they were originally deposited in the same chemical condition as we now see them, without the subsequent aid of any igneous operations, is perfectly evident; and the occasional occurrence of *pebbles and shells* of the carboniferous system in the magnesian limestone, coupled with the known fact that certain beds of the carboniferous limestone contain a large proportion of magnesia, might lead us to conjecture that the one is derived from the ruins of the other. But, as Professor Sedgwick observes in discussing this subject, (*Geological Transactions*), all the magnesian beds in the carboniferous limestone would be quite insufficient for the purpose, and the *crystalline character* of the Mansfield and other varieties of magnesian limestone clearly negatives this mechanical solution. Beds rich in magnesia alternate with others devoid of that substance, the same beds are in one tract magnesian, in another yield pure lime, and in general we must be content to shelter our ignorance under the statement that from some unknown cause the waters of the sea were then decomposed in such a way as to permit very generally the precipitation of united magnesian and calcareous carbonates—the possible circumstances of which must be intrusted to the examination of the Chemist.

The salt and gypsum usually associated in this remarkable system present also their difficulties. Not that it is hard to suppose the waters of the ancient sea to have been so evaporated as to permit first the crystallization of sulphate of lime, and finally of muriate of soda. But in this case we should expect to find almost uniformly over the whole area regular strata of gypsum below, and regular layers of salt above, while, in fact, we more commonly find salt in great broad masses rather than beds below, and gypsum in scattered masses above. A general drying of the waters in which the saliferous system was deposited is plainly inconsistent with probability; and we must have recourse to local causes, something analogous perhaps to those which influenced the deposit of primary limestone. It may be conceivable that the solubility of muriate of soda in water is capable of diminution through the admixture of other substances in the liquid, or through the effects of great pressure, or of pressure and heat combined; it may be maintained that the limited deposits of salt happened in separated lagunes of the sea, exposed to local desiccation, as perhaps in Cheshire. Mr. Lyell has still a different and less probable view of the subject. All these explanations assume that the salt was produced directly by mere crystallization, from waters almost perfectly analogous to those of the actual seas; an assumption strongly confirmed

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by the recent discoveries connected with bromine and iodine.

Further researches, both Chemical and Geological, must determine between these and other theories, and

in particular, we must be more exactly informed of the ancient hydrography of the salt districts, which, in almost every instance, must have been very different from their present topographical features.

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*Table of the Organic Remains of the Saliferous System.*

The asterisk distinguishes such as are known to occur in other systems of strata.

PLANTS.				
Family.	Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Precilic Sandstone. Locality in Magnesian Limestone.
Algæ	Fucoides Brardii			{ Frankenberg copp. slate.
	selaginoides			Mansfeld, ditto.
	frumentarius			Ditto.
	pectinatus			Ditto.
	digitatus			Ditto.
Cryptogamia	lycopodioides			Ditto.
	Equisetum Meriani	Neue Welt near Basle.		
	*columnare	Württemberg		Sulzbach, or Soultz.
	clatodon.	Franken in Wurtem.		
	Calamites prenceus.	Ditto		{ Wasselone, Marmoutier.
	Mougeottii			Marmoutier.
	remotus			Wasselone.
	Pecopteris Meriani	Neue Welt.		
	*arborescens			Near Autun.
	*abbreviata			Ditto.
Various families.	Tæniopteris *vittata	Neue Welt, Stuttgart.		
	Anomopteris Mougeottii			Soultz, Wasselone.
	Neuropteris Voltzi			Soultz.
	elegans			Ditto.
	Gaillardoti		Luneville.	
	Sphenopteris myriophyllum			Ditto.
	palmetta			Ditto.
	Filices Stuttgartensis	Stuttgart.		
	lanceolata	Ditto.		
	scelopendioides			Ditto.
	Lycopodites Haenflinghausi			{ Eisleben near Mansfeld.
	Cycadeæ			
	Pterophyllum longifolium	Neue Welt.		
	Meriani	Ditto.		
	Jægeri	Franken, Stuttgart.		
	enerve	Neue Welt.		
	Mantellia cylindrica		Ditto.	
	Convallarites erecta			Ditto.
	*nutans			Ditto.
	Palaeoxylon regulans			Ditto.
	Echinostachys oblongus			Ditto.
	Æthiophyllum stipulare			Ditto.
	Marantoidea arenacea, Jæger.	Stuttgart.		
	Voltzia brevifolia			Ditto.
	elegans			Ditto.
	rigida			Ditto.
	acutifolia			Ditto.
	pterophylla			Ditto.
	Asterophyllum ? bulbosa			Thuringerwald.

The following plants, which are well known in the coal strata, occur in the lowest red sandstone. (Rothe-todteliegende.)

- \*Lepidodendron Sternbergii.....Hinkelheim in the Spessart.
- \*imbricatum.....Weidenbrunn near Rothenburg.
- \*Stigmaria Veltheimiana.....Magdeburg?

Other vegetable relics at Amrode, Seibigkerode, be-

tween Friedeburg and Rothenburg; Kyffhaeuser, Meisdorf, Endorf.

The names in this list are taken from M. Brongniart, who supposes the flora of the variegated sandstone system to be of a peculiar type. It is certainly very analogous to that of the succeeding or oolitic epoch, by its pterophylla and equiseta, but the genus Voltzia is perhaps peculiar to it.

## POLYPARIA.

Name.	Locality in Magnesian Limestone.
Gorgonia anceps, Goldfuss	Glücksbrunn in Thuringerwald.
antiqua, G.	Glücksbrunn.
infundibuliformis, G.	Ditto.
*Calamopora spongites, G.	Ditto, (and Ural.)
Retepora flustracea, Phil.	Durham.
virgulacea, Phil.	Ditto.
Astræa-pediculata, D.	

The absence of polyparia from the muschelkalk is one of the characters by which it approximates to the lias.

## RADIARIA.

Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Magnesian Limestone.
<i>Ophiura prisca</i> , Miln. ....	Vosges Mountains.	Baireuth.	
<i>loricata</i> , G. ....	Schwenningen.		
<i>Asterias obtusa</i> , G. ....		Marbach.	
<i>Eucrinus moniliformis</i> , Mil. ....		General in this rock.	
<i>ramosus</i> , Schl. ....			Glücksbrunn.
<i>Pentacrinus dubius</i> , Gold. ....		? Rudersdorf.	
* <i>Cyathocrinus planus</i> , Mil. ....			Durham.

## ANNULOSA.

Name.	Locality in Muschelkalk.
<i>Serpula valvata</i> , G. ....	Baireuth.
<i>colubrina</i> ....	?

By its radiaria, amongst which no echinus is mentioned, the muschelkalk resembles the lias, those radiaria which lie in the magnesian limestone present greater analogies to the older rocks.

## CONCHIFERA.

Family.	Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Preilitic Sandstone.	Locality in Magnesian Limestone.
Plagymyona	<i>Cardium pectinatum</i> , v. Alberti	Württemberg.	Württemberg.		
	<i>striatum</i> , Schl. ....		Ditto, Göttingen.		
Trigonia	<i>vulgaris</i> , Schl. ....	Ludwigsburg	Weimar, Göttingen.	Dompfaff, Soultz	
			Württemberg, Baireuth.		
	<i>curvirostris</i> , Schl. ....	Ditto, Schwenningen.	Württemberg.		
	<i>sulcata</i> , G. ....	Villingen.			
	<i>pes anversis</i> , Schl. ....		Göttingen, Morsbach, Luneville.		
	<i>cardisoides</i> , G. ....		Württemberg.		
Mya	<i>lavigata</i> , G. ....		Marbach.		
	<i>Goldfussii</i> , v. Alberti		Ditto		
	<i>musculoides</i> , Schl. ....	Sultz on the Neckar	Weimar, Württemberg, Upper Silesia, Poland.	Sulzbach.	
	<i>elongata</i> , Schl. ....	Ditto ditto	Württemberg, near Waldshut, Upper Silesia, Poland.		Sulzbach.
Modiola	<i>ventricosa</i> , Schl. ....		Württemberg, Luneville.		
	<i>maetioides</i> , Schl. ....		Marbach, Upper Silesia, Poland.		
	<i>rugosa</i> , v. Alberti		Rottweil		
Mytilus	<i>modiola</i> , G. ....	Rottweil.			Durham.
	<i>acuminata</i> , Sow. ....				Aberford, Durham.
Mytilus	<i>velutius</i> , G. ....		Göttingen, Württemberg, Luneville.	Dompfaff, Sulzbach	
	<i>eduliformis</i> , Schl. ....		Baireuth.		
	? <i>keratophagus</i> , Schl. ....				Glücksbrunn.
	? <i>striatus</i> , Schl. ....				Ditto.
	<i>squamosus</i> , Sow. ....				Fennybridge Yorkshire.
Venericardia Goldfussii v. Alberti		Rottweil.			
<i>Saxicava Blainvillii</i> , Haen. ....		?			
<i>Venus nuda</i> , G. ....			Marbach.		
— Sedg. ....					Durham.
<i>Maestra? trigona</i> , G. ....			Ditto		
<i>Axius obscurus</i> , Sow. ....					Yorkshire, Durham.
<i>Astarte</i> — ? Sedg. ....					Wibby, Northumb.
<i>Area inaequalis</i> , G. ....			Freudenstadt.		
<i>tumida</i> , Sow. ....					Durham.
<i>Cucullaea minuta</i> , G. ....			Villingen		
<i>sulcata</i> , Sow. ....					Ditto.

An uncertain bivalve shell is found in the rothetodteliegende at Mansfeld.

Murchisonia	<i>Plagiostoma lineatum</i> , Schl. ....	Württemberg	Morsbach, Michelstadt, Göttingen, Württemberg, Baireuth, Weimar.	
	<i>striatum</i> , Schl. ....		Very common.	
	<i>rigidum</i> , Schl. ....		Jena.	
	<i>lavigatum</i> , Schl. ....		Morsbach.	
	<i>punctatum</i> , Schl. ....		Göttingen, Gotha, Weimar, Baireuth, Toulon.	
	— ? Sedg. ....			Ditto.

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	Mesomyona.	<i>Avicula socialis</i> , Schl. ....	Sulz on the Neckar	{ Very generally dis- tributed .....	Sulzbad, Dompstal.		
		<i>subcostata</i> , G. ....	Ditto .....	Württemberg, Baireuth.			
		<i>lineata</i> , G. ....	Ditto.				
		<i>crispata</i> , G. ....		Friedrichshall.			
		<i>Brouni</i> , v. Alberti .....		Villingen.			
		<i>costata</i> .....			Sulzbad.		
		<i>gryphæoides</i> , Sow. ....				Durham.	
	Posidonia	<i>Keuperiana</i> , Voltz ..	Swabia, Hall.				
		<i>minuta</i> , v. Alberti ....	Rottweil.				
	Ostrea ?	.....				Whitby.	
		<i>placunoides</i> , Mün. ....		Baireuth.			
		<i>subanomia</i> , M. ....		Ditto.			
		<i>reniformis</i> , M. ....		Ditto.			
		<i>difformis</i> , Schl. ....		Württemberg.			
		<i>multicostata</i> , M. ....		Würzburg.			
		<i>complicata</i> , G. ....		Baireuth, Villingen.			
		<i>decemcostata</i> , M. ....		Baireuth.			
		<i>spondylioides</i> , Schl. ....		Very general.			
		<i>conta</i> , G. ....		Rottweil.			
		<i>pleuronectites</i> , Schl. ....		{ Bourbonne les Bains, Luneville.			
	Gryphæa ?	<i>præsa</i> , G. ....		Villingen.			
	Pecten	<i>reticulatus</i> , Schl. ....		Göttingen, Gotha.			
		<i>Alb. rti</i> , G. ....		Villingen, Rudersdorf			
		<i>laevigatus</i> , G. ....		{ Württemberg, Bai- reuth, Gotha.			
		<i>discites</i> , Schl. ....		{ Württemberg, Pohlen, &c.			
	Perna	<i>vetusta</i> , G. ....	Dürheim.				
Brachiopoda		<i>Langula tenuissima</i> , Bronn ..	Rottweil.	Rottweil.			
		<i>Orbicula speluncaria</i> , G. ....				Glücksbrunn.	
		<i>Terebratula communis</i> , Bosc. }		{ Göttingen, Würtem- berg, Luneville, Bourbonne les Bains, Toulon.			
		<i>vulg. et subrot.</i> Schl. }					
		<i>perovalis</i> , Schl. ....		Jena.			
		<i>sufflata</i> , Schl. ....		Ditto .....		?	
		<i>orbiculata</i> , Schl. ....		Near Jena.			
		<i>cristata</i> , Schl. ....				Röpsen.	
		<i>elongata</i> , Schl. ....				Schmerbach.	
		<i>complanata</i> , Schl. ....				Gera.	
		<i>intermedia</i> , Schl. ....				Röpsen, Schmerbach.	
		<i>inflata</i> , Schl. ....				Ditto, ditto.	
		<i>lacunosa</i> , Schl. ....				Ditto, ditto.	
		<i>paradoxa</i> , Schl. ....				Schmerbach.	
		<i>pelargonata</i> , Schl. ....				Ditto.	
		<i>pygmaea</i> , Schl. ....				{ Leimstein near Schmalkalden.	
		several species .....				Durham.	
	Delthyris	<i>spirifer</i> , Sow. .... }		Villingen.			
		<i>semicircularis</i> , G. .... }					
		<i>trigonalis</i> , Sow. ....				Röpsen.	
		<i>undulatus</i> , Sow. ....				Durham.	
		<i>multiplicatus</i> , Sow. ....				Ditto.	
		<i>minutus</i> , Sow. ....				Ditto.	
	Leptæna, or Producta }	.....				{ Thalitter, Goldels- heim, Büdingen, Logan am Quieiss, Durham.	
		<i>aculeata</i> .... }					
		<i>speluncaria</i> , Schl. ....				Röpsen, Glücksbrunn	
		<i>rugosa</i> , Schl. ....				Röpsen.	
		<i>antiquata</i> , Sow. ....				Durham.	
		<i>costa</i> , Sow. ....				Ditto.	
		<i>spinosa</i> , Sow. ....				Ditto.	
		<i>*longispina</i> ? Sow. ....				Schmerbach.	

N.B. A species of *terebratula* is found in the rothotdtehegende at Mansfeld.

The general result of an examination of the fossil conchifera of the saliferous system, is, that in the upper strata a general analogy to the oolitic era can be recognised by the trigonæ, plagiostomata, ostreae, &c.; and in their productæ and spiriferæ the lower strata as distinctly claim affinity with the carboniferous limestone.

## GASTEROPODA.

Family.	Name.	Locality in Keuper	Locality in Muschelkalk.	Locality in Porcelline Sandstone.	Locality in Magnesian Limestone.
Holostomatæ	<i>Calyptæa discoides</i> , Schl. ....		Villingen.		
	<i>Capulus</i> , or <i>Pileopsis</i> }		Ditto.		
	<i>mitratus</i> , G. .... }				
	<i>Dentalium torquatum</i> , Schl. ....		Göttingen.		
	<i>laeve</i> , Schl. ....		{ Ditto, Alpirsbach, Baireuth.		

Geology. Ch. II.	Family.	Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Porcelline Sandstone.	Locality in Magnesian Limestone.	Geology Ch. II.
	Holostomata	<i>Trochus albertinus</i> , G. ....		Rottweil.			
		<i>Pleurotomaria</i> ? .....				Durham.	
		<i>Turbo</i> ? <i>dubius</i> , Mün. ....		{ Seewangen, Riedern, near Waldshut.			
		? <i>giganteus</i> , Schl. ....		Seewangen.			
		<i>Turritella obsoleta</i> , Schl. ....		Weimar, Göttingen.		{ Yorkshire, Durham, Derbyshire.	
		<i>deperdita</i> , G. ....		Weimar.			
		<i>detrita</i> , G. ....		Culmbach.			
		<i>scalata</i> , Schl. ....		{ Würtemberg, Rü- dersdorf.			
		? <i>terebralis</i> , Schl. ....		Weimar	Domptail, Sulzbad.		
		<i>Schoteri</i> .....			Sulzbad.		
		undescribed .....				Yorkshire.	
		<i>Melania</i> .....				Durham.	
	Solenostomata	<i>Buccinum turbidum</i> .....	Sulz on the Neckar.	{ Würtemberg, See- wangen, Rüders- dorf.			
		<i>gregarium</i> , Schl. ....		Rüdersdorf.			
		<i>antiquum</i> , G. ....			Sulzbad.		

## CEPHALOPODA.

Name.	Locality in Muschelkalk.
<i>Nautilus bidorsatus</i> , Schl. ....	Weimar, Rüdersdorf, Göttingen, Würtemberg, Luneville.
<i>nodosus</i> , Mün. ....	Franken.
<i>Ammonites nodosus</i> , Schl. ....	Weimar, Göttingen, Würtemberg, Lorraine, Toulon, Tarnowitz.
<i>bipartitus</i> , Gaill. ....	Luneville.
<i>sempartitus</i> , Schl. ....	
<i>Rhyncholites Gaillardoti</i> d'Orb. ....	Jena, Göttingen, Würtemberg, Luneville, Rechanvillers.
<i>hurudo</i> , Fauv. ....	Würtemberg, Luneville.

These cephalopoda are characteristic of the muschelkalk. The ammonites belong to a section of that numerous genus, distinguished by peculiar sutures. (See Von Buch's Essay on the subject of the sutures of ammonites. (*Ann. des Sci. Nat.*))

## CRUSTACEA.

Name.	Locality in Muschelkalk.
<i>Palmaris Suerni</i> , Desm. ....	Villingen, near Saarbrück.

## VERTEBRALIA.

Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Magnesian Limestone.
Fishes .....	{ Seidmannsdorf, Neuses, Sei- dingstadt, near Coburg. .... }	Baireuth,	
<i>Palæothrissum</i> , Blain. ....			
<i>P. macrocephalum</i> , Bl. ....			Mansfeld, Durham
<i>magnum</i> , Bl. ....			Ditto, ditto.
<i>maculatum</i> , Bl. ....			Rothenburg, near Autun.
<i>macropteron</i> , Bronn. ....			Thüringen.
<i>parvum</i> , Bl. ....			Rothenburg, near Autun.
<i>blennioides</i> , Hall. ....			Mansfeld.
<i>elegans</i> .....			Durham.
<i>Freislebene</i> , Bl. ....			Mansfeld, Hesse.
<i>Stomatopus major</i> , Bl. ....			Hesse.
<i>gibbosus</i> , Bl. ....			North of Germany.
<i>Clupea Lunethenii</i> , Bl. ....			Eisleben.
? .....			Seefeld in Tyrol.
<i>Chetodon</i> ? .....			Durham.
Other fishes .....			Seefeld.
Teeth of <i>Squalus Raja</i> .....	Würtemberg	Würtemberg, Rüdersdorf.	

These remains of fishes lie in marl or copper slate at the bottom of the zechstein and magnesian limestone formation.

Name.	Locality in Keuper.	Locality in Muschelkalk.	Locality in Magnesian Limestone.
<i>Phytosaurus cylindricodon</i> , Jæg. ....	Boll.		
<i>cylindricodon</i> , Jæg. ....	Ditto.		
<i>Mastodonsaurus Jägeri</i> , Holl. ....	Gaillardorf.		
<i>Ichthyosaurus Lunevillensis</i> .....	Würtemberg	Luneville, Würtemberg.	
<i>Plesiosaurus</i> .....	Dürheim	Würtemberg, Baireuth, Rüdersdorf.	
<i>Crocodylus</i> .....		Rüdersdorf.	
<i>Monitor antiquus</i> , Cuv. ....			{ Mansfeld, Rothenburg, Glücks- brunn.
Large saurian .....		Luneville.	
<i>Chelonia</i> .....		{ Ditto, Bindlocher, and Leineck- erburg	

## GENERAL SUMMARY.

Plants.....	Marine.....	6 ; wholly confined to the zechstein.
	Cryptogamia .....	23 ; of which six are stated to occur in other systems of strata.
	Gymnospermia, &c.....	17.
Zoophyta...	Polyparia .....	7 ; all confined to the zechstein group ; one found in another system of strata.
	Radiaria .....	7 ; confined to the muschelkalk and zechstein ; one repeated in carboniferous limestone.
Articulosa...	Annulosa .....	2 ;
	Crustacea .....	1 ; in muschelkalk.
Mollusca....	Conchifera plagyryna .....	32 ; eight of these occur in England in magnesian limestone.
	mesomyona .....	32 ; three of these occur in England in magnesian limestone.
	brachiopoda .....	28 ; eight of these occur in England in magnesian limestone.
	Gastropoda holostomata .....	17 ; four of these occur in England in magnesian limestone.
	solenostomata .....	3.
	Cephalopoda.....	6.
Fishes .....		15 ; four occur in England in magnesian limestone.
Reptiles.....		9.
205 ; of which about thirty occur in England in magnesian limestone.		

*Disturbances of the Saliferous System.*

In England dislocations of a very extensive nature are but rarely exemplified in strata more recent than the coal measures. It appears that this part of the surface of the Globe enjoyed a long and rarely interrupted immunity from those violent agencies which had previously shaken its strata into such disturbed positions. A few faults in the magnesian limestone range of Durham and Yorkshire, as along the line of the great whindyke through those Counties, in the country between Doncaster and Ferrybridge, and South of Doncaster, may be mentioned rather as exceptions to the general rule, effected in some indefinite portion of the long period succeeding the deposit of coal ; and the curious parallel faults of Aust cliff on the Severn, which affect both the lias and red marl, deserve attention, in connection with the law formerly laid down of faults underlying depressed portions of strata. (p. 541.)

Neither on the Continent of Europe are the dislocations of the saliferous system so remarkable as those of the older strata. In the Vosges mountains we have, however, a splendid example of a dislocation on a great scale, by which, in a direction North East and South-West, the lower strata of this system (*grès des Vosges*) are thrown up into bold mountains, while the upper beds of the same system (muschelkalk and keuper) are left several hundred feet below the magnificent escarpment. In fact, it appears that this eruption happened during the saliferous epoch, after the date of the *grès des Vosges*, and before the muschelkalk and keuper were deposited.

In the South-West of Brittany, in La Vendée, in Morvan, De Beaumont describes dislocations which appear to have preceded the lias ; and from observations on the Böhmerwald and Thüringerwald it appears that the elevation of these ranges of mountains followed the saliferous epoch, and preceded the lias and oolites. Of the same era are some dislocations defining the primary ranges near Avallon and Autun.

Several cases, then, appear to show unconformity and interruption of continuity between the variegated marls and the oolitic formation above. But these are but local effects ; parallelism of strata generally prevails between these contiguous systems, indicating freedom from general disturbance, and in some instances, especially in Somersetshire, the frequent changes of colour in the upper red marls, and finally the interposition of a purple or black marl, which is not more related to the lias than to the saliferous system, appear to show that even in the

nature of the deposits there is no more decided difference between them than between any other successions of strata.

*Oolitic System.*

The oolitic system of strata has for the most part its ranges parallel, and its declinations accordant to the saliferous rocks, and was deposited in the same marine basins. The general character of the rocks, and the nature of the organic remains is however extremely different, but the change from the one system to the other, though seldom to be called gradual, is accomplished by remarkable repetitions. In particular, the muschelkalk of Germany and France represents, even in mineralogical characters, but most decidedly in its suite of organic exuvia, the lias, which is at the base of the oolitic system. Through all the mass of the oolitic system, consisting of various limestones, clays, and sands, the most remarkable repetitions occur. The mass of lias contains beds very nearly approaching to the ferruginous inferior oolite ; three or four separate beds of very similar oolite, several beds of sand and sandstone also remarkably analogous, and many thick strata of clay hardly distinguishable except by their organic reliques, make up this vast argillo-arenaceous-calcareous mass, of which the top changes, by repeated introductions of green sand layers, to the real cretaceous system, as the bottom has been before shown to be connected with the saliferous group.

The composition of this system varies much in different Countries of Europe, according, probably, to the differences of depth of the original waters, proximity to land, to mouths of ancient rivers, &c. In consequence, while on the border of Switzerland it is almost wholly calcareous, in Westphalia and in England its limestones are much intercalated with clay, and occasionally with carboniferous sandstones and shales, hardly to be distinguished from those of the older coal strata. A remarkable absence of metallic substances is a character of the calcareous portions of this system (excepting the lias) in all its extent.

The most distinct classification of the oolitic system will be obtained from the combined section of the English series ; for though the total thickness of the deposit is perhaps greater in the South East of France and in Switzerland, the number of divisions is there less, the mass more uniformly calcareous, and the parts less characteristic.

The oolitic system of England everywhere admits of  
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the following mode of subdivision, though in some tracts particular groups are concealed by unconformity or entirely wanting. The groups are placed as they occur in nature, or the series is descending.

- |  |   |  |
|--|---|--|
| 5. Wealden formation.                    | { | A series of clays, sandstones, and limestones, mostly of fluviatile origin, and containing remains of land and fresh-water animals and plants, deposited in estuaries or other local hollows of the really marine portion of the oolitic system.   |
| 4. Upper or Portland oolite formation.   |   | Calcareous, sometimes oolitic rocks, associated with green and iron sands, resting on blue clay, altogether marine deposits. When the Wealden formation is absent (as happens in the greater number of instances) this terminates the whole system, and graduates into the cretaceous rocks above.                           |
| 3. Middle oolite or coralline formation. | { | Consisting of oolite and other limestone strata, included in calcareous gritstones, and resting on blue clay and calcareous gritstone: altogether marine deposits.   |
| 2. Lower or Bath oolite formation.       |   | Consisting of two or more strata of oolite, with other calcareous beds, and alternations of sands and clays, which in particular districts enlarge themselves into real coal tracts. Altogether marine and littoral deposits.  |
| 1. Lias formation.                       | { | Consisting principally of argillaceous clays, more or less laminated, and including, especially in the lower part, layers and nodules of generally argillaceous limestone, and in the upper part bands and strata ferruginous, calcareous, and arenaceous, which strongly resemble the bottom of the lower oolite formation. |

### Oolitic System.

A further analysis of these formations presents us with the following details.

- |  |   |  |
|--|---|--|
| 5. Wealden formation of Kent, Sussex, and Hampshire              | { | <i>Weald clay.</i> Thick blue clays, generally destitute of organic remains, except in certain calcareous beds, which contain fresh-water shells.  |
|  |   | <i>Hastings' sands.</i> Thick series of sandstones, with partings of clay, and subordinate beds of limestone, with bones of saurians, fluviatile shells, and land plants.                              |
|  | { | <i>Purbeck beds.</i> Blue clays and laminated limestones with fluviatile shells.   |
|  |   | <i>Portland oolite.</i> Oolite and earthy and compact limestones with marine shells, and layers of nodular chert.  |
| 4. Upper oolite, formation of Portland, Wilts, Bucks, Berks, &c. | { | <i>Shotover sand.</i> Calcareous sand and concretions.   |
|  |   | <i>Kimmeridge clay.</i> Thick blue clay, bituminous, with septaria and marine remains, and especially in the lower part, bands of sandy concretions, thus establishing a gradation to the next system. |

3. Middle oolite formation of Oxford, Berkshire, Yorkshire, &c.

2. Lower oolite formation in Gloucestershire, Oxfordshire, and Northamptonshire

N. B. All this part of the series is differently composed in Yorkshire and the North of Scotland.

Coralline oolite group.

Oxford clay group.

- |   |   |  |
|---|---|--|
| Upper calcareous grit, with marine fossils.   | { | Coralline oolite, so named from two or three separate beds of irregular occurrence, rich in zoophytic exuviae. In the lower part the beds alternate with those of the next rock; all of them contain marine exuviae. |
| Clay 10 feet. Lower calcareous grit, with marine shells, graduating below into the Oxford clay. |   | Oxford clay, with septaria, fossils, &c.; the lower part a subordinate bed, called Kelloway rock, which is a calcareous grit, (rarely oolitic,) very rich in fossils.  |
| Blue clay dividing Kelloway rock from the cornbrash.  | { | Cornbrash limestone, a coarse, shelly rock of variable and small thickness, but remarkable continuity.   |
|   |   | Sand with concretions of sandstone and nodules of fissile arenaceous limestone.  |
| Forest marble group.  | { | Coarse shelly oolite, in some places slaty.  |
|   |   | Sandy clay or grit.  |
| Great oolite.   | { | Blue clay.   |
|   |   | A calcareous and mostly oolitic rock, of variable thickness and changeable nature, the upper beds shelly.  |
| Fuller's earth group.   | { | A series of marls and clays with included beds of soft marly or sandy limestones and shells.   |
|   |   | A coarse, often very shelly rock of limestone, irregularly oolitic, occasionally interlaminated with sand, especially in the lower part.   |
| Inferior oolite   | { | Ferruginous sand with concretionary masses of sandy limestone and shells   |

- |  |   |  |
|--|---|--|
| Upper lias clay or shale, full of belemnites and other fossils, intercalated with or graduating to the sand above, and in some cases containing nodules and bands of limestone.  | { | Marlstone. A suite of calcareous, sandy, and iron beds, very rich in fossils, and much analogous to the lowest bed of the lower oolite formation |
| Lower lias clay or shale, full of fossil remains, interlaminated with bands and nodules of limestone, especially in the lower part, where a collection of these layers constitutes the lias rock.  |   |  |
| Lias rock. A suite of laminated limestones, with partings of clay, blue, grey, and white, the former in particular containing gryphites and other shells; the latter usually devoid of organic remains. This rock is sometimes consolidated into a united mass, and sometimes divided into separate portions. It rests on the red marl in the North of England, and on blue, black, or purple marls, which cover that formation in the South of England. | { |  |

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Range of lias.

The lias formation is observed on the Southern coast of England, at Lyme Regis, from whence passing under the unconformable green sand of Blackdown, and surrounding the irregular elevations of carboniferous limestone in Somersetshire, it ranges uninterruptedly by Bath, Gloucester, Leicester, Newark, and Gainsborough, to the Humber. At this point the course of the oolitic system is very much narrowed by the overextension of the chalk; and at Bishop Wilton the chalk rests on the lowest part of the lias formation, which has a superficial breadth of only a few yards. It, however, expands again towards the North, and shows itself very completely developed on the coast of Yorkshire. Detached portions of this formation accompany the saliferous system in Glamorganshire, and lie unconformably in the

hollows amongst elevated ridges of carboniferous limestone.

Through the whole of this range some general physical features, almost constant mineralogical qualities, and prevalent species of organic reliques, fix such a decided character upon the lias formation as to establish a good geological horizon for the guidance of the English observer.

The country which it occupies is in general a broad vale at the foot of the escarpments of oolite, and terminating towards the red marl by a very connected range of uniform low hills. A considerable portion of the steep slope of the oolite escarpments is occupied by the lias; and in the Midland Counties, particularly, owing to the action of currents of water, detached portions of

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oolite crown the summits of many insulated masses of the upper lias shales.

From the coldness and stiffness of the soil, much of the surface of the lias clays remains in pasture, for which it is particularly well adapted; and where the plough has in former times been employed, the land is thrown up into very high ridges for the sake of surface drainage. Water is scarce in this tract, and, because of the abundance of pyrites, often sulphureous or ferruginous, or impregnated with purgative salts, as sulphate of soda.

A general tendency to an argillaceous type belongs even to the limestones of the lias formation, and its clays more frequently exhibit a schistose structure than the other clays of the oolitic system. Layers and masses of jet are frequent in it, especially in the Northern part of its course; pyrites is one of its most abundant productions, especially in connection with ammonites and other shells, and sulphur in some parts is so prevalent as to furnish a valuable manufacture of alum. Many fruitless trials for coal along the line of the lias clays are upon record, to serve as a warning to those unacquainted with Geology.

Very remarkable organic exuviae belong almost equally to every part of the English lias. Skeletons of saurian and chelonian reptiles, several species of scaly fishes, abundance of ammonites and belemnites, plagiostomata, gryphææ, &c. and considerable quantities of the wood of coniferous trees, enable the Naturalist to form very reasonable views of the state of the ancient land and sea when this formation was in progress, and serve not only to identify it in all parts of England, but even over a large part of its extent in France and Germany.

Nevertheless, there are important geographical peculiarities connected with the lias of England, which deserve a short analysis, the better to enable us to perceive the circumstances under which the ancient sedimentary deposits of the sea took place.

The section of the lias, as it exists in Yorkshire and Lincolnshire, is peculiarly instructive and complete, and forms an excellent type with which to compare the detached portions of the formation in North Britain and the South of England. We shall take the groups in the ascending order of their antiquity.

**Lias limestone.** The calcareous beds included in this division are in the North of England very distinctly divided into two or more portions separated by considerable thickness of clay.

1. The lower limestone, 10 to 20 feet thick, is not traced further North than the Humber. It consists of compact blue or grey limestone, generally laminated and shelly, with partings of whitish clay or marl. It rests immediately upon the red marl and gypsum.

2. Clay, 50 to 100 feet, with layers of nodules, often septariae, full of pentacrinites, ammonites, plagiostomata, &c.

3. Upper lias limestone, 12 to 20 feet, in rough, shelly, coarsely laminated beds, separated by partings of clay. The colour usually brown, but in wet pits and before exposure to the air internally blue. But the most remarkable character of these beds is, the astonishing abundance of gryphææ incurva which they contain, or rather of which they almost wholly consist. In several parts of Lincolnshire the roads are mended with the most beautiful specimens of this fossil, and for miles together hardly any other shells can be collected from this part of the lias.

Lower lias clay or shale, 300 to 500 feet thick, a dark homogeneous clay or shale, with many layers of argillo-calcareous nodules, seldom containing shells, and in the lower part rough sandy beds. Coniferous wood, pentacrinites, plicatulæ, gryphææ Maccullochii, pinna folium, and several ammonites, &c. occur in this stratum, but in it organic remains are not particularly abundant, and neither belemnites, terebratulæ, nor saurians are so plentiful as in the beds above. No alum is made from this part of the lias shale.

Marlstone series, 100 to 150 feet, consisting of highly arenaceous shales, and laminated sandy limestones of brown, greenish, or grey colour, succeeded above by several bands of nodular ironstone, the whole series particularly abundant in shells, besides producing beautiful stellerida, annulosa, and fishes. Several species of terebratulæ, cardium truncatum, dentalium giganteum, &c. appear almost confined to these strata, which likewise contain gryphææ, pectines, plagiostomata, terebratulæ, and modiolæ, not distinguishable from the ordinary fossils of the oolite. The marlstone beds are in fact the first term of the oolitic deposits, interpolated among the last terms of the lias, and, according as the clay above them is attenuated or developed, they may be ranked with the oolitic, or the lias formation. In the North of England, the former mode of arrangement *must* be adopted, but in the South, the latter has been often followed.

The upper lias clay or shale, 50 to 200 feet in thickness, is the aluminous rock of Yorkshire, and passes by intermixture into the marlstone series below, and by a gradual change into the analogous sandy beds of the oolites above.

It contains a multitude of layers of argillo-calcareous nodules mostly aggregated round ammonites and other organic bodies, and these are particularly remarkable and of larger size in the lower part of the shale, which also is much harder than the rest. A profusion of ammonites, belemnites, and nautili, accompanied by aviculae, inocerami, amphidesmata, &c., besides abundance of ichthyosauri, and plesiosami, jet, and remains of coniferous wood, enrich this interesting rock. Its thickness is variable, amounting to 200 feet on the coast, but diminished to 50 feet, or even less, in some of the Cleveland hills, where also the usual smooth homogeneous texture of aluminous shale is changed to a decidedly sandy composition.

Proceeding to the South, we find the characters of the lias formation of Yorkshire maintained with considerable exactness through the Counties of Nottingham, Lincoln, Leicester, and Rutland, into Oxfordshire. The section from Lincoln to Gainsborough shows clearly the upper lias clay, marlstone group, lower lias clay, gryphite limestone, and laminated limestone, all superimposed on gypseous red marl. In the vale of Bedford, likewise, through Rutland, and as far as the centre of Oxfordshire, we have the lower laminated limestone (1.) surmounted by a thick clay, (2.) in which lie gryphitic beds peculiarly shelly, which Mr. Conybeare calls *upper lias* beds, and which correspond to the gryphitic beds of Lincolnshire. Still higher, are beds of green or brown marly sandstone, with terebratulæ, pectines, belemnites, and other shells, which are always ferruginous, and, in Rutland particularly, laminated and entirely similar to some of the marlstone beds of Yorkshire. Above these, in the same tracts, lie 100 or even more feet of clay, often forming insular

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hills between valleys of marlstone, and upon the whole the ferruginous sand of the inferior oolite.

If any doubt has at any time been raised as to the real distinction in this country of upper lias clay, marlstone, lower lias clay, and double course of lias limestone, it has probably arisen from the extreme resemblance of the ferruginous marlstone of the Vale of Belvoir which divides the upper from the lower lias clay to the ferruginous sandstone which is the general floor of the oolitic rocks. In Rutland, however, the distinction is perfectly evident.

Lias of the  
Cottswold.

Through Oxfordshire and Gloucestershire the upper lias clay continually becomes thinner, and the marlstone beds in consequence approach nearer to the sand of the inferior oolite. It is no wonder, therefore, that they should be in these Countries sometimes confounded. But the section of Painswick Hill, near Stroud, adduced by Mr. Conybeare, (*Geology of England*, p. 252.) sufficiently proves that the same principle of classification applies to the lias below the Cottswolds, as well as to the North-East moorlands of Yorkshire. In fact, by merely taking the argillaceous beds which in this section separate the sands of the oolite from those of the marlstone, and calling them upper lias clay, the accordance with the Yorkshire section is perfectly evident. This question has been effectually settled by Mr. Lonsdale's recent and most valuable investigation of the Cottswolds. That excellent observer has clearly established the identity of the lias system of Gloucestershire with that of Yorkshire, in general terms; at the same time defining the amount of topographical difference which principally affects the upper lias shale.

In the Southern parts of Gloucestershire, and in the vicinity of Bath, the upper lias clay becomes still more attenuated, and the marlstone beds more divided and mixed with the clay. Mr. Smith gave the name of marlstone to the laminated stony beds full of pectines and other shells which are found in the Somerset canal and other places, twenty feet or less below the sand of the inferior oolite, as may be noticed in his sections. In several places, these beds, from the deficiency of the clay above, are brought nearly into close contact with the sand of the inferior oolite.

Whether this distinction of marlstone beds can be carried further South into Dorsetshire does not yet appear.

From Mr. Lonsdale's Essay in the *Geological Transactions*, we find the lias limestones to be thus arranged in the descending order.

	Feet.
Blue lias. Consisting of beds of greyish argillaceous limestone, varying in thickness from 2 to 18 inches, and separated by others of blue marl which are generally less than 6 inches thick, but sometimes more than 2 feet	50 to 60
White lias. Thin strata of yellowish white argillaceous lias-tone, with partings of pale brownish clay	10
Lias lower marl. Dark grey marl with calcareous concretions	20

Organic remains of ammonites, belemnites, pectens, oysters, &c. though most abundant in the blue lias, are more or less diffused through all the beds.

Combining the section of the North of England with Mr. Lonsdale's and Mr. de la Beche's sections of the lias in the vicinity of Bath and Lyme, we shall have the following general table of the complete type of the English lias.

1. Upper lias clay, marl, or shale. Upper lias shale. (Phillips.)
2. Marlstone beds.

3. Middle lias clay ..... { Upper lias marl. (Lonsdale.)  
Lower lias shale. (Phillips.)  
Gryphitic and laminated lias of North of England.
4. Lias limestones and marls ... {
5. Lower lias marls ..... { Blue and white lias of Bath.  
Of Lyme Regis and Bath.

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These lower marls are thus described by De la Beche, at Culverhole, near Lyme, (section descending.)

	Ft. In.
Dark marl	3 0
Earthy dark grey limestone	0 10
Dark grey slaty marl	5 0
Irregular light grey limestone	0 10
Dark slaty marl	1 4
Compact grey limestone	0 10
Dark slaty marl, which rests on the light bluish green beds belonging to the upper part of the new red sandstone system	7 0
Total...	18 10

Mr. Murchison's *Memoirs on the Oolitic Deposits of North Britain*, most clearly prove the existence of well-characterised lias shales, much like those of the Yorkshire coast, in Pabba, Skye, and other of the Western Isles, and the organic remains which he collected there are of the usual English types. Lias occurs also on the North-East coast of Ireland, as at the Giant's Causeway, with ammonites and belemnites.

The lias in South Wales is a singular extension of the formation among the dislocations of the older carboniferous system, nearly analogous to its appearance among the sandstones and slates of Scotland. The Valley of the Ely, in South Glamorganshire, exhibits several upfittings of lias, commencing about five miles West of Landall, whence, with some interruptions, they accompany the Ely to its junction with the Channel near Penarth Point. It again appears in Barry Island, and continues to skirt the coast in a Westerly direction nearly to the mouth of the Ognore river, forming a range of bold cliffs, among which is the little harbour of Aberthaw, celebrated for the lime which it exports. (Conybeare, *Geology of England*.)

We may now turn our attention to the general types of lias presented in the North and South-East of France, and in various parts of Germany.

As in England, so generally in these Countries, the lias is deposited conformably to the saliferous system, but in Brittany and around the plateau of primary rocks in central France, especially about Autun, the oolitic system often touches the granitic series without any interposition of red sandstones. In the district which borders that plateau on the East, between Chalons and Autun, the oolitic rocks are considerably developed with lias at the bottom, and all based upon gypseous red marl; but the lias clays are here almost wholly deficient, and the formation consists only of the gryphitic limestone, with its partings of clay. The abundance of gryphaea incurva, and other characters of the stone, strongly remind the traveller of the analogous beds in Lincolnshire. The lias and oolites are so closely allied that Desnoyers, in his description of this tract, hesitates even to distinguish the former as a fourth stage of the calcareous or oolitic system.

South of the Ardennes mountains by Luxemburg, Metz, and Nancy, the lias exhibits more developed characters. Immediately upon the Keuper marls rests a considerable bed of sandstone, white, yellow, or rarely brown, sometimes solid, and sometimes friable; gradually passing into the lias beds above. From its

Lias in  
North Br  
tain.Lias in  
France and  
Germany

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abundance under and around the fortress of Luxembourg, it receives in that Country the name of *grès de Luxembourg*.

The proper gryphitic lias limestones succeed and cap most of the plateaux of grit. The beds are bluish and compact, and alternate with grey friable marls.

Above are grey marls and marly grits, which correspond to the lias clays and marlstone of England; and these are followed by the ferruginous sandstones which form the general floor of the oolitic system.

In Würtemberg, and, perhaps, generally on the German side of the Rhine, the lias has more of the character of the English series both as to mineralogical composition and organic remains. In particular, the saurian reliquæ, so abundant in the lias clays of England, are all found in those of Boll and other parts of Würtemberg, and with some additional species have been described by M. Jäger, of Stuttgart. Fine specimens of saurian animals occur in many of the museums along the Rhine. But, perhaps, the most remarkable accordance between the series of Germany and that of England, is observed at Banz near Coburg, where the Maine crosses the Northern extremity of the Franconian range of oolites. Here Mr. Murchison has observed the following section.

Sandstone cap of the lias .....	300 feet thick.
Upper lias shale of Yorkshire .....	40
Marls and marlstones .....	150
Lower lias shale, with compact lias and ammonites <i>Hawkerensis</i> , near the top .....	300
Gryphite limestone .....	
Gritstone .....	
Keuper formation .....	

At this place the most astonishing profusion of saurians, fishes, crustacea, ammonites, nautili, and belemnites, as well as pentacrini, gryphites, and other fossils, occur, and many of them remarkably agree as to their place in the strata with the arrangement of the same species in the beds of the coast of Yorkshire.

L. Swiss-land

Lias shales occur below the Alpine or Jura limestone of Switzerland and Savoy, and occasionally, as at Meyringen, Bex, the Mont Joux, produce some of the characteristic ammonites and belemnites of the English lias. In the Valley of the Arve, in particular, the argillaceous beds of lias are immensely thick, and owing to the igneous agency, once so powerfully excited beneath the Alps, have a schistose character strongly assimilating them to the primary slates. Whether the slates of the Valorsine belong to the same era is, perhaps, not yet ascertained; but if this should be proved, the vegetable remains which they contain, being identical with those of the carboniferous epoch, would indicate that these regions enjoyed a particular immunity from the causes which, in all other instances yet examined, had wholly destroyed the plants which grew in the carboniferous epoch, and covered the earth with cycadæ and other entirely new types of vegetable life.

#### Lower Oolite Formation.

The uninterrupted range of this formation through Dorset, Somerset, Gloucestershire, Oxon, Northamptonshire, Rutland, and Lincoln, to the banks of the Humber, may be seen on the Maps of Mr. Smith or Mr. Greenough. Beyond the Humber it is concealed for a short distance beneath the overlying chalk, but emerges again, and occupies a vast breadth in the Eastern part of Yorkshire. In Sutherland, and in some of the Hebrides, and particularly in Skye, it has been traced by Mr. Murchison.

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It occupies, through all its course in England, an elevated range of hills with bold escarpments to the West or North-West, a gentle slope to the East or South-East, and deep valleys of denudation which often, by descending to the lias clays, furnish most complete information as to the relations of the two formations. The surface of the calcareous portions is dry and bare of trees, and wells sunk therein often reach a very considerable depth, while upon the alternating clays the soil is cold or wet, and, in general, much covered by woods. The fertility of the district is below the average of the secondary strata. The highest point of the range in the South of England is Cleve Pipard Hill, near Cheltenham, 1134 feet above the sea, and in the North of England, Botton Head, near Ingleby in Yorkshire, 1485 feet; but in these cases about two-thirds of the height consists of the lias clays.

The more ordinary altitudes of the oolitic range in England are 700, 800, and 900 feet, varying according to the Westward extension of the hill, the thickness of the base of lias, and the pile of incumbent strata.

Certainly, this regular and continuous range of oolites, with so nearly uniform an elevation of escarpment, is one of the most characteristic features of English Geology, and furnishes matter for profound reflection. For like the parallel, equally continuous and regular, and but slightly lower range of chalk, its elevation seems not at all due to local disturbances, but rather appears to indicate a general intumescence of the land in the direction of these ranges. The low vales of lias, Oxford clay, and Kimmeridge clay, which intervene between the lower, middle, and superior oolite ranges, have undoubtedly been caused, at least in part, by the erosive action of water; but to whatever extent we apply this principle in explaining the present inequality of the earth's surface, and whatever aid we receive for the established data of local elevation, these limited agencies always leave unexplained the general fact, *viz*, the regular altitude of continuous ranges of hills with uniformly declining planes, and no particular marks of convulsion, which overlook extensive undisturbed plains of older strata.

The vicinity of Bath, where Mr. Smith began his important researches, furnishes the general type of the lower oolite formation; and, with some modifications, the series of strata here presented, as detailed by Mr. Smith and Mr. Lonsdale, is found to be almost universally reconcilable with the phenomena of the other oolitic districts. The variations observed are principally caused by the interpolations of a larger proportion of arenaceous, argillaceous, and carbonaceous beds, so as in extreme cases to change the calcareous section of Bath into a coal field, with subordinate beds of limestone. Such is especially the case in the Eastern moorlands of Yorkshire, at Brora in the Hebrides, and in the gorge of the Weser at Minden, as observed by Mr. Murchison.

The table of classification given above, will make known the order of succession of groups recognised in this formation, and we shall now proceed to point out their characters and notice their variations more exactly.

The SAND which is the base of the inferior oolite group in the vicinity of Bath, possesses, in general, only a slight degree of cohesiveness, but in places passes into a friable sandstone. It is micaceous, of a yellow colour, and contains irregular courses of calcareous concretions

Escarpments of oolite.

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called sand burrs. These nodules are often aggregated round ammonites and other organic bodies. The thickness of this bed sometimes amounts to 70 feet.

The inferior oolite varies in thickness, in some places being 60 feet, in others considerably less. The rock, according to Lonsdale, admits of being characterised in three portions, the lower one 6 feet, hard, of a brown colour, abounds in casts of trigonia, luna, trochi, &c., and is seen in many sections reposing immediately on the sand. The coated muscles, as they are termed, are found in this bed, and the bed which in the descending quarries yields so immense an abundance of species is apparently of the same date. The middle division, 10 feet, is a rubbly stone; principally consisting of crystallized carbonate of lime, through which the organization of astrea may be clearly traced. It is, therefore, a coral bed, and as might be supposed is of irregular occurrence.

The upper portion of the rock, 40 to 50 feet at the utmost, contains the workable freestone or oolite of this rock, the upper part, in particular, cannot be distinguished in specimens from the great oolite above. The lower beds are more sandy, browner, and less oolitic.

The fuller's  
earth group

The fuller's earth group, so named from the occurrence in it of limited beds of that substance, is a thick argillaceous deposit with a few layers of nodular limestone and indurated marl, occurring on the hill sides of Bath, and distinctly separating the inferior from the great oolite. The following is Mr. Lonsdale's summary of these beds.

	Feet.
1. Blue and yellow clay with nodules of indurated marl	30 to 40
2. Bad fuller's earth	7 to 5
3. Good fuller's earth, brown or blue	2½ to 3
1. Clay containing beds of bad fuller's earth and layers of nodular limestone (fuller's earth rock) and indurated marl	100

The great  
oolite rock

The great oolite rock contains, besides the more perfectly oolitic parts, which hold few shells and furnish the best freestone, a great number of beds, in which the oolitic structure is less evident or even wanting, and which are more or less filled with remains of shells, corallines, &c. These coarser portions of the rock lie at the top and bottom, and enclose the purer oolite between them.

The lower rags consist of several beds of coarse shelly limestones 10 to 40 feet; the lowest bed of it which rests on the fuller's earth group is fine-grained and scarcely oolitic.

The oolitic beds in the middle are very variable in thickness and quality. On Combe Down the thickness sometimes amounts to 30 feet. The stone when taken from the quarry is quite soft, and holds so much water as to be beaten to a pulp by the hammer. After being thoroughly dried it will absorb more than one-seventh of its weight of water, but by long exposure it grows harder and less absorbent. It will not stand the sea air, though in the neighbourhood of the quarries it is very durable.

The upper rags, 20 to 55 feet, consist of alternating beds of coarse shelly limestones, tolerably fine oolite sand, tough, used by the Romans in their buildings at Bath, and are some of these beds are full of millepores and other porous univalve and bivalve shells. They often exhibit that peculiar variety of internal lamination called

false bedding, when the ingredients of the stone form layers inclined to the plane of stratification.

The forest marble group admits of the following subdivision in a descending order:

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The forest  
marble  
group.

	Feet.
6. Clay with occasional laminae of grit	15
And at Norton St. Philip a layer of rubbly indurated marl abounds with fragments of a small oyster and terebratula.	
5. Sand and nodules, or beds of calcareous gritstone	40
The sand is reddish-yellow or white, pure or mixed with clay, or lime. The gritstone, usually of a brown but sometimes of a blue colour, exists in spheroidal masses which have a laminated structure parallel to the stratification, and occasionally can be split into flags.	
The fracture often shows shining facets of interposed carbonate of lime. Organic remains are generally rare in these beds, sometimes particularly abundant.	
4. Clay with thin slabs of stone and laminae of grit	10
3. Coarse oolite or shelly limestone (forest marble) full of fragments of wood and shells, especially ostraea and plagiostoma, bones, teeth, &c. The majority of the beds have a fissile structure, and can often be split into thin flags, or tiles, oblique to the plane of stratification.	
Thin partings of clay generally divide the beds.	
2. Sand, or sandy clay and grit	10
1. Pale blue or grey clay, enclosing thin slabs of tough brownish limestone and laminae of calcareous sandstone or grit. The thickness variable	5 to 10

The cornbrash consists of numerous rubbly beds of coarse limestone, mixed with clay, altogether 10 to 15 feet thick. The beds, or rather nodules, are extremely irregular, and of different colours, but they are pretty uniformly composed of tough granular limestone, and abound with terebratula, avicula echinata, rocardia, amphidurata, &c.

In tracing the lower oolite formation to the South from the Bath district, the inferior oolite is found to become more ferruginous (Sturthorne) and with its subjacent sand to cap the lias as far as Badport but the great oolite soon "thins out," while the forest marble group thickens and becomes predominant. The cornbrash retains its usual characters and fossils.

In the district lying North of the Humber the lower oolitic system assumes entirely new characters which will require separate consideration. The beds seen in the imperfect exhibition of these oolites near Cave, where they divide the lias from the Oxford clay, are the sand of the inferior oolite covered by shelly and oolitic beds, a continuation of the oolite of Lancashire, and above them a thin bed of pale blue clay. They are here much diminished in thickness, and, though burnt to lime, somewhat debased in purity. On the banks of the Derwent, the lias is surmounted by the same simple series, with the addition of beds of calcareous flagstone above. Further along the range, at Brand by and Wigantoupe, the series is expanded by the interposition of beds of sandstone and shale, with a thin band of coal between the sand which caps the lias, and the shelly limestone which here represents the oolite of Lancashire. Above the limestone runs a band of pale blue clay, and upon this rest a succession of beds of sand and sandstone, enclosing spheroidal concretions of calcareous sandstone with glistening facets, often blue in the centre and full of shells, some of which resemble those of Stonesfield. Beds of sandstone, sand, and carbonaceous matter are also interpolated above this slaty rock. The oolite here is hardly deserving of

Lower  
oolite  
Yorkshire

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that name from its lithological character, for though this appearance sometimes presents itself, the greater part of the stone is a coarse, granular, shelly limestone, with imbedded shells, &c. It is, in fact, the oolite of Cave still more degenerated. The series of sandstones and shales with coal which here overlies the sandstone cap of the lias, has been supposed analogous in position to the fuller's earth group of Bath, (the similar series which overlies the limestone beds corresponds to the interval between great oolite and cornbrash,) and as we proceed Northwards both series increase immensely in thickness, so that the lower one reaches 500 feet, and the upper one 200; and as, from local circumstances, the coal, though never more than 16 inches thick, is worth working, these moorlands assume the appearance of a true coal field, with subordinate beds of very coarse shelly limestone. It requires, indeed, very close observation to trace the thin limestone beds across these vast moors, and amidst such a number of sandstone beds. They are best studied on the coast. The sandstone upon the lias is here a variable rock often coarse and fragmentary, sometimes with the characters of ordinary sandstone, but generally subcalcareous, ochraceous, and full of shells and casts. At Blue Wick, near Robin Hood's Bay, it presents a double band of fossil-bearing beds, the lower one gradually passing to the subjacent lias. The limestone appears with different aspects at different points. Under Grinsthorp cliffs it recalls pretty exactly the oolite of Cave, but at Scarborough, Cloughton, Hawsker, Sneaton, &c., it is a very different rock, coarse, fragmentary, and mixed with veins of earthy and argillaceous oolite, so as to be scarcely fit to be burned to lime. In the Stauntondale cliffs it is a double band, at Whitenab it is covered by calcareous sandstone slate, in which glistening facets, like those in the stone of Brandsby, and Wattering, occur. Only one seam of coal is worked in the district, and it lies beneath the limestone. The cornbrash appears on the coast, also, in a debased but recognisable form. The fossil plants which accompany the coal seams and sandstones, may also be detected in the limestones and calcareous slates both on the coast and at Brandsby; and it is worthy of particular attention, that both at Collyweston and at Stonesfield, several of these plants occur in the slate, as brachyphyllia, ferns, and cycadites. No marine exuviae have yet been found in these coal grins or shales, but some bivalves resembling anodon, which perhaps were swept down with the ferns, equiseta and cycadens, are found at Grinsthorp. In several places, a particular part of the section of lower carboniferous sandstones, exhibits the remarkable phenomenon of equiseta standing irregularly erect over considerable areas in a bed of sandstone which rests upon shale.

This is, therefore, truly a coal field of the oolitic era, produced by the superposition of vast quantities of sedimentary deposits brought down by floods from the land, between the more exclusively marine strata of the ordinary oolitic type. We may believe this to be a case of a littoral deposit of oolite, and should naturally derive it from that supposition, the debasement of quality and attenuation of thickness of the shelly limestones, in proportion as the spoils of the land brought down into the sea were more abundant. Whatever the causes were which produced these effects, they were not entirely local. The Yorkshire oolitic district is indeed the only tract yet investigated in England which exhibits these effects in a striking manner; but attentive consideration

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of the phenomena presented by the rag beds of oolite and coarse shelly beds of forest marble near Bath, and still more the wavy surface and vegetable fossils of some kinds of the sandstone slate of Ridge, Stonesfield, and Collyweston, will lead to the conclusion that these portions of the oolitic formation were deposited within the influence of the littoral agitation of the sea. (Mr. Scrope has presented a notice of this subject to the Geological Society.)

Another fact is important. The extensive additions of terrestrial plants and sediment are confined to the intervals between the sand which is the base, and the cornbrash which is the cap of the lower oolite formation.

Mr. Murchison's examination of Brora and other Lower points in Sutherland, and of the Western coast of oolites in Scotland, has proved the extension of the carboniferous system of the Yorkshire oolites into these Northern regions, and it is interesting to observe that there, as well as in Yorkshire, the interpolations occupy the same limited space in the section.

The following short summary of the beds in these Countries will prove this point:—

#### Section of Brora.

Middle oolite formation consisting of . . . . .	Calcareous grit and Oxford clay.
	Shelly limestones representing cornbrash and forest marble.
	Alternations of sandstones, shales, and ironstones with plants
	Ferruginous limestone, blue in the interior, with fragments of carbonized wood and abundance of shells.
Lower oolite formation, consisting of . . . . .	Sandstones and shales of great thickness in frequent alternations with plants, having in the upper part . . . beds of coal, of which the upper one is 3 ft. 8 in. thick, the lower one, not worked, 1 ft. 4 in.
Lias formation with fossils of the Yorkshire lias.	

#### North-East Coast, Isle of Skye.

Sandstone series.	
Shelly limestone.	
Sandstones and shales of great thickness, with obscure impressions of plants and abundance of carbonaceous matter.	
Calcareous sandstone beds, with small nodules of indurated limestone grit, with fossils and thin layers of shale with bellerophonites	
Blue shale (upper lias shale of the Yorkshire coast) with small blue calcareous concretions, bellerophonites, &c	
Sandstone with concretionary nodules and fossils of the marlstone series	
Lias shale— <i>Geological Transactions New Series</i>	

The same Geologist has found a considerable analogy to these phenomena in the section presented by the gorge of the Weser, where that river escapes through the Porta Westphalica into the plains of Northern Germany. How unlike to the general type of the oolitic formation of the German and Swiss Jura!

Having thus produced the two most contrasted types yet discovered of the lower oolite formation, and by their comparison put a severe check upon the doctrine of universal formations (if such was ever entertained) among the secondary strata, it will be useful to state the leading features of this formation in the intermediate parts of its range, in England, and thus to ascertain the parts which vary, and the method of their variation. To do this with entire satisfaction is not easy, and indeed requires more data, yet the curious fact of the

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oolites in  
Mulland  
Counties.

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continuity of the cornbrash above, and of the lower oolite sand below, from one end of England to the other, by furnishing every where exact limits to the formation, very much abridges the inquiry and diminishes the chances of error. In the long range from the coast of Dorsetshire to the coast of Whitby, the character of the lower sand varies, yet not so much as is common to sandstones, the principal difference consisting in the colour which is occasioned by the degree of oxidation of the iron. Through Oxfordshire, Rutland, Lincoln, and the Southern part of Yorkshire, it is a very dark brown ferruginous rock, whence it is often called "gingerbread stone," frequently enclosing shelly concretions, (Banbury,) occasionally enveloping beds of limestone, and sometimes (Northampton, Rockingham) interlaminated by white beds of oolite. The quantity of oxide of iron is sometimes so considerable as to divide the mass of the rock into a multitude of ochraceous cells or "iron boxes." In some places, especially in Lincolnshire, it consists of an alternating series of white and brown sand.

With respect to the cornbrash it is sufficient to say, that though so unimportant a rock in other respects, it is probably more continuous, and more uniform in its character from Dorsetshire to the Humber, as may be seen in Mr Smith's Map, than any other member of the lower oolitic formation except the sand of the inferior oolite.

Lincolnshire presents the following section of this formation: (observations made in 1821:)

Cornbrash full of its usual fossils.

Clay thin.

Thin shelly beds, in one locality, somewhat resembling the blue beds of Farley near Bath.

A considerable thickness of clay ground, presumed by Mr Smith to include the forest marl system of Wiltshire.

Sandy laminated stone, in a few localities South of Lincoln.

Thick, apparently undivided, oolitic rock, very productive of organic remains, with polypterous bed, on the top.

In the upper parts of this rock, false bedding is frequent, coarse shelly rags abound, good oolite is dug at Ancaster. This is undoubtedly the same rock as that of Gage in Yorkshire, and it is continuous with the same general character as far as Grantham, between which place and Stamford there appears to be some change.

Inferior oolite sand.

Between Stamford and Peterborough the series was recorded thus: (1821:)

Cornbrash.

Clay of some thickness.

Sandy laminated bed, at Pilgate

Interval not known.

Rag beds of Barnack

Stamford oolites, and

Inferior oolite sand.

On the line from Wandsford, through Weldon to Rockingham: (1821:)

Cornbrash very distinct.

Clay of some thickness, nothing else observed.

Weldon oolite or rag, the same as the Barnack rag

Interval, presumed to be clay, under some breadth of Rockingham forest.

Brown sand of Rockingham Hill, with interlaminated white limestones.

It might appear from these statements that the slates of Wittering and Collyweston are near the Northern end of these deposits: they are unknown at present in a distinct form North of the Welland, except at Market Deeping, though probably represented by the sandy cap of the Lincolnshire oolites.

The slate of Collyweston is associated with beds of

oolite and compact limestone, and presented to Mr Murekison and the author the following detailed section.

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Local Names.	Fl. In.	Description.
Rubble .....	4 0	Imperfectly bedded oolite.
Cale .....	4 0	Irregular and broken beds of oolite.
Bedding sand ..	1 3	Fine yellow sand indurated at top and at bottom into concretionary and slaty layers.
Broad .....	4 0	Brown hard oolite graduating upwards to the sandy layers above. Thin beds, not bent to lime.
Limestone ....	1 6	Hard, compact, not oolitic, containing brachyphyllum, ferns, and trigonolites.
Bech .....	1 2	Irregular sandstone.
Slate .....	2 to 1 0	Masses irregularly spheroidal flattened, very fissile, in general calcareous grit not at all oolitic, but shelly, with littoral and terrestrial plants.
Fine sand ...		Of a yellowish colour.

The slate is quarried only in Winter, for if dried by the Summer Sun and wind, it hardens and will not split. The holes are blocked up in Spring, and the quarrymen only employed in preparation of slate. It is, in general, very equally laminated. The splitting is caused by organic exuvæ.

The Stonesfield slates near Oxford have been almost universally esteemed of the same age as these Collyweston rocks.

At Stonesfield two beds of concretionary masses, capable of being easily (with the assistance of frost) split into slaty parallel to the stratification, compose with sand and friable sandstones a group 5 or 6 feet thick, under 50 feet of alternations of laminated shelly oolite and thin blue clay. The following is Dr. Fitton's account of the section. (*Zool. Journal*, vol. iii.)

Rubbly limestone

Clay with terribatinites

Limestone.

Blue clay.

Oolite.

Blue clay

"Rag," consisting of shelly oolite, with casts of brachy and univalves.

"Soft stuff," 6 in. yellowish-sandy clay with thin courses of fibrous transparent gypsum.

"Upper Head," 1 ft 3 in. to 1 ft 6 in. sand enveloping a course of spheroidal laminated calcareous grit stones which produce the slate. These are called "Pot-bells" from their figure, and receive with the other slaty bed the name of Pendle, as characteristic of the workable stone. The stone is partially oolitic and shelly, sometimes full of small fragmentary masses.

"Mamie or Rag," 1 ft. slaty friable grit rock.

Lower Head 1 ft. 6 in. to 2 ft. sand and grit, including a course of spheroidal concretions of slate like that described above.

Bottom stuff, 1 ft. sandy and calcareous grit with admixture of oolitic grains.

The slate beds consisting of

The slate beds consisting of

The floor of the slate beds is rag like the oolite above. Most of the Stonesfield fossils, and in particular the jaws of *diplephidæ*, have been extracted from one or other of the courses of slate.

We may now return to the Bath series of oolites, and accompany Mr. Lonsdale in his recent survey of their extension to the Northward.

Lincolnshire.

Collyweston slates.

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oolites of  
Gloucester-  
shire.

The *inferior oolite* in the South of Gloucestershire consists of nearly equal divisions of soft oolite and slightly calcareous sand; but in the Northern division of the County the latter, for the greatest part, is replaced by a yellow sandy limestone. The freestone beds, which are not to be lithologically distinguished from those of the great oolite, gradually increase in number and thickness from the neighbourhood of Bath to the Cotswold, East of Cheltenham, where they constitute the whole of the escarpment. This vertical importance is retained through the North of the country examined; but to the Eastward of the valley, ranging from Stow on the Wold to Bartington, near Burford, a change takes place both in the structure and thickness of the formation. The freestone beds are there replaced by strata of nodular coarse oolite, containing numerous impressions of *clippus sinuatus*, the sandy portion consists of only a thin bed, and the thickness of the whole of the inferior oolite group is diminished from 150 to about 50 feet.

The *fuller's earth* loses its importance in proceeding Northward, yet it was traced as a parting between the great oolite and the inferior oolite, as far as a line passing from the neighbourhood of Winchcomb to Burford, but to the North-East of this line it thins out.

*Great oolite.* The threefold arrangement of upper rags, fine freestone, and lower rags, into which this rock is naturally divided near Bath, does not prevail uniformly in our progress Northward.

The upper rags, consisting of soft freestone and hard shelly oolite, were traced to Cirencester; but to the North-East of that town they are replaced by a rubbly, white, argillaceous limestone. The beds of the middle division become chiefly a hard oolitic limestone. At Wotton under Edge the lower rags are replaced by beds of fissile calcareous sandstone, which runs through the whole of Gloucestershire to the neighbourhood of Burford. They are extensively worked as a tile-stone, possess the lithological character of the Stonesfield slate, have their fissile property in the same way developed by exposure to atmospheric agency; contain *Trigonia impressa*, the characteristic fossil of Stonesfield; and on comparing the strata of Burford with those which rest at Stonesfield on the slaty beds, it was found that an almost perfect identity of character and order of position prevailed at the two localities. The Windrush quarries near Burford give the following section for comparison with that of Stonesfield previously detailed.

Top. Rubbly limestone . . . . .	1 foot
Brownish marlstone . . . . .	6
Rubbly limestone . . . . .	4
Pale sandy marl . . . . .	3
Rubbly limestone . . . . .	$\frac{1}{2}$
Light-coloured clay . . . . .	$\frac{1}{2}$
Rag and freestone . . . . .	15
Sandy laminated grit . . . . .	—

Mr. Lonsdale has thus corrected the almost universal error of English Geologists in classing the Stonesfield slate with the forest marble, and has assigned its true place at the base of the great oolite; a most important alteration in every point of view.

The forest marble was found to possess the same characters as near Bath, consisting of a thick stratum of laminated shelly oolite, interposed between beds of sandy clay, containing laminae of grit; and to have, from

Bath to near Fairford, for its uppermost stratum, a deposit of loose sand, containing large masses of calcareous grit.

It is hardly to be doubted that the slate of Collyweston is coeval with that of Stonesfield, but it must be left to further investigation to decide whether the thick oolites of Lincolnshire comprise both the great and inferior oolite of Bath, or which of them exists there alone. It is now ascertained that there are calcareous slaty beds in two points of the series between the corn-brash and the inferior oolite, it is known that both the great oolite and inferior oolite are subject to great variation of lithological character and thickness, and that the fuller's earth which distinguishes these rocks at Bath is extinct, or nearly so, North of Burford. The problem, therefore, now presented to Geologists by the yet unfinished survey of the oolites, is rather complicated, and demands much labour to perform with full effect. It should be begun by taking up the subject where Mr. Lonsdale's observations end, viz. at Burford, and the ground examined minutely Northwards. We may venture to promise that this will not be wholly neglected.

#### Middle Oolite Formation.

Very strong analogies accompany all the leading divisions of the oolitic system, and mark them as the products of a succession of similar causes. As the oolites of Bath lie enclosed between strata of calcareous sand, so those of the middle division are imbedded between strata of calcareous sand and sandstone, and the association of the upper oolite with green sands at Swindon and Thame, is probably of the same intimate description. The organic fossils of all the divisions have a striking general resemblance, and the composition of the rocks is liable to similar variations.

The physical features impressed on the geography of the country which they traverse are also very similar. As the consolidated strata of the lower oolite formation form a high escarpment, which overlooks the plains of argillaceous lias; so the limestones and sandstones of this middle group rest on a bold edge, above the vales of Oxford clay, and the upper oolite rocks in the few places where they occur domineer in the same manner over the vales of Kimmeridge clay. It might have been attended with some convenience to have considered these thick clays as formations apart from the rocks, as the lias has been separated from the lower oolite, but they are from various causes so connected with them that it would have injured the practical utility of the classification.

The general characters of the surface of the middle oolite formation, are a moist valley of Oxford clay below a dry range of hills, furnishing copious springs from the calcareous grits and oolite. Dry valleys, deep walls, narrow dells, washed by the rapid streams, occur, especially in the districts of greatest altitude, and one unacquainted with the series of formations might recognise in the general aspect of *this*, the description usually given of the lower oolite range. Outlines of the oolites and sandstones occasionally cover insulated hills of the subjacent clay, and prove the denuding power of ancient floods. The altitude of this range of oolite nowhere equals that of the lower oolite in the same region. Thus while in Yorkshire the rocks rise in Botton Head to 1185 feet above the sea, the former reach on Black Hambleton 1249 feet. In Oxfordshire

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Range and  
extent.

and Gloucestershire 800 or 900 feet is the height of the lower oolite, but 400 or 500 feet that of the middle oolite.

This formation is upon the whole less continuous than the one described before, yet the discontinuity is not of the whole mass, but chiefly of the group of oolites and sandstones. These have a considerable developement in Dorsetshire; first on the coast at Weymouth, and secondly from near Sturminster to beyond Wincanton, where they produce oolitic freestone. Hence to Longleat Park they are unknown. From Longleat their range is unbroken by Westbury, Calne, Wootton Bassett, Highworth, Farringdon, and Abingdon, to the banks of the Thames at Oxford. They can be traced under Shotover, and towards Brill, a few miles, but their further course is unknown, till we arrive under the Wolds of Yorkshire near Acklam. At this point emerging from beneath the chalk, they encircle the Vale of Pickering by Malton, Helmsley, Pickering, and Scarborough, increase greatly in importance, and assume more completely than in any other part of England, excepting perhaps Weymouth, the full characters of their formation. But while the oolitic group is thus dismembered into four widely detached regions, the Oxford clay beneath is as remarkably connected from the North side of the Dorsetshire downs, by Wincanton, Melksham, the Vale of the Isis, Otmoor, the Vale of Bedford, Huntingdon, the Western border of the Fens, and the Vale between the Cliff and Wold ranges of Lincolnshire to the banks of the Humber. Beyond the unconformity of the chalk wolds, its course is undivided beneath the slope of the calcareous grit round the Vale of Pickering to Scarborough.

We shall now offer a few details of the internal structure and variations of these rocks.

The clay below the Kelloway rock has been very little noticed, and is indeed not very important. It occasionally contains pholadomyæ and other shells near Bath, and more frequently abundance of selenite, and on the coast of Yorkshira has yielded some curious remains of crustacea. As for the greater part of the range of the Oxford clay the Kelloway rock is unknown, this clay can seldom be distinguished. In Yorkshire it barely reaches a few yards, and generally is less than three feet in thickness.

Kelloway  
rock.

The Kelloway rock, so named by Mr. Smith from Kelloway Bridge in Wiltshire, which is almost the only place where it occurs in the South of England, is in that County more remarkable for the beauty, peculiarity, and abundance of ammonites, gryphææ, and other organic remains which it produces, than for either its thickness or continuity. It is there a calcareous sandstone, appearing when devoid of organic remains very similar to those which accompany the coralline oolite, externally brown, internally grey or blue, of a rubbly nodular structure, altogether less than twelve feet thick. From Wiltshire to Northamptonshire no mention is made of this rock, but it was found with its usual fossils at Boziate Hill, near Wellingborough, by the writer of this Article, in company with Mr. Smith in 1820.

In 1821, the same observers established the occurrence of the Kelloway rock at Hackness and Scarborough on the sea-coast of Yorkshire. It is coextensive in that County with the range of the Oxford clay, from under which it rises into an escarpment. It arrives sometimes at a thickness of sixty feet, and is then locally distinguishable into several portions. It is, however, altogether a

mass of sand and calcareous sandstone, with or without organic remains; the upper beds very thick, indurated by admixture of oxide of iron, and multitudes of gryphææ, belemnites, ammonites, and aviculæ, and other fossils. Not unfrequently in the vicinity of the shells it becomes sufficiently calcareous to assume the character of a sandy oolite, sometimes ferruginous like that of Dundry. The sandy parts of the mass are often variously stained brown, reddish, yellow, or even perfectly white, in layers or irregular stripes, and traversed by disseminations of oxide of iron. In a very few places it is useful as a building stone.

There is perhaps no more curious fact on record than the occurrence of this apparently indefinite rock, with almost identical characters, after so great an interruption of continuity.

The Oxford clay (clunch clay of Smith) appears, in Oxford the whole of its range South of the Humber, a pale blue clay, turning yellow on the surface, with large sparry septaria, and some layers of chocolate-coloured shale, (Tytherton,) with ammonites and other fossils. In Yorkshire, it is less tough, and more generally laminated, gradually changing in quality to the Kelloway rock below, and the calcareous grit above. Most of the organic remains which it yields belong to the lower part of the stratum, and are in general identical with or very similar to those of the Kelloway rock. Taken in general terms, the suite of fossils at Weymouth belonging to the Oxford clay is considerably allied to that of the Kelloway rock and Oxford clay of Yorkshire, but further comparison of the species of ammonites is yet needed. In the Museum at Strasburg fossils of the Kelloway rock, as well as of the Oxford clay, are recognised.

It is painful to observe the dreadful waste of money in ill-advised trials for coal along the line of the Oxford clay. The least fragment of jet or morsel of bituminous shale, especially if accompanied by "blue metal," is enough to make a credulous proprietor listen to an ignorant collier, and throw away the value of his solid land in seeking for the imaginary treasures beneath it.

The lower calcareous grit should be carefully distinguished from the iron sand, with which Mr. Smith has occasionally confounded it, nor is the distinction difficult, for, independent of its geological position, the calcareous grit is not particularly ochraceous, and never assumes that dark ferruginous aspect so remarkable in the other rock. In Wiltshire, where it was first observed, it appears as a thick stratum of sand, inclosing irregular beds of sandstone, or of calcareous grit, which assumes the aspect of coarse limestone. These sandstones are brown externally, but grey or blue within. Irregular layers of clay occur in places, and friable beds of decomposed shells. The prevailing colour of the sand is yellow, but sometimes it is ash-coloured. At Studley, near Oxford, Dr. Buckland detected a peculiar bed of clouded grey colour, and very tough and dense texture, a sort of argillaceous chert, rich in pinnæ, ammonites, and other organic remains. It probably belongs to the lower part of the rock.

The calcareous grit of Heddington, also rich in organic remains, ammonites, belemnites, *plagiostomata*, *pectines*, &c., is a very coarse rock, with an abundant admixture of quartz pebbles, chiefly of small size, and fragments of shells. It forms irregular beds and concretions in beds of quartzose sand, mixed with calcareous matter.

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Coralline  
oolite  
group.  
Lower calc.  
grit, &c.

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Professor Sedgwick's description of the calcareous grit of Weymouth makes us acquainted with a more complete series than that of Wiltshire and Oxfordshire. The following statement of beds there is in the ascending order:

- a. The lowest beds upon the Oxford clay are black, and meagre to the touch, filled with irregular branching stems like *alcynona*.
- b. Thin beds of yellow sand and sandstone.
- c. Strong ferruginous jointed beds of calcareous grit.
- d. Blue argillaceous beds, alternating with hard compact beds with an even fracture.
- e. Yellow sand like *b*, with beds of calcareous grit in the upper part.

Beds of oolite succeed.

Lower calc  
grit York-  
shire, &c.

The section of the lower calcareous grit on the Yorkshire coast between Filey and Scarborough has a striking resemblance to that of Weymouth. Immediately on the Oxford clay rests a series of grey marly sandstones, 70 feet thick, gradually becoming more yellow and more consolidated upwards, till they assume the harshness which belongs to stones usually called cherty. This cherty bed appears to correspond with that mentioned before at Studley. It continues across the moors to Hambleton. Above these runs a band of yellow sand, nine feet thick, enclosing large spheroidal highly indurated calcareous balls. This band is traceable through the interior, where it forms rabbit-warrens, as far as Whitestone Cliff, and there the balls are of immense size. When they fall out, the rock looks cavernous. The upper part of the rock consists of strong beds of calcareous sandstone, very remarkably covered on the surface, and also penetrated by branching cylindrical bodies, which continually remind us of sponges. The upper beds of this series are of a redder colour, and more calcareous than the others, remarkably full of shells, and in some places alternate with two or three beds of oolitic limestone also shelly. In the interior of the moors, they are often used for wallstone. It is not always quite easy to draw the line between them and the oolite above, especially when the latter is unusually shelly, and no coral bed intervenes.

According to Mr. Lonsdale there is in Wiltshire a pale blue clay, 10 feet thick, interposed between the lower calcareous grit and the coralline oolite.

The coralline oolite, or coral rag group, as described by Smith, Conybeare, and Lonsdale, near Oxford, Wootton Bassett, and Bath, seems not so complete a series as that described by Professor Sedgwick at Weymouth, and by other authors in Yorkshire.

Weymouth.

The thickness of the whole group is greater in Yorkshire than elsewhere, but no where in that country exceeds 80 feet. The section at Weymouth gives above the calcareous grit the four following groups:

- f. Many beds of pure oolite with beds of argillaceous partings, alternating with other shelly oolitic beds, somewhat resembling forest marble. In some of these beds the oolitic particles are associated with a variety of marl, and are incoherent.
- g. Thin beds of oolitic marl, containing innumerable specimens of the small *clypæus clunicularis*, casts of *melania*, &c.
- h. Beds of impure sandy oolite, containing, besides other fossils, a few specimens of *ostrea deltoidea*.
- i. Thick limestone series, at the bottom of which lie masses of coral rag, containing *caryophyllia annulata*, *astræa*, &c. with innumerable fragments of *trigonia clavellata*. In the higher portion are many meagre sandy beds, nearly resembling the lower calcareous grit, but more calcareous, and with a finer suite of organic remains.

Coralline  
oolite Wilt-  
shire.

Mr. Lonsdale describes the Wiltshire coral rag in three divisions which do not succeed one another in any

certain order, but rather intermix with and replace one another. One of them, from which the formation takes its name, is an irregular mass of nodules mostly crystallized, but sometimes earthy, and connected together by pale bluish clay. These nodules consist of little else but corals of the genera *astræa*, *caryophyllia*, and *agaricia*, especially the former, which sometimes separately compose the whole mass. The lower part of this bed sometimes affords a dark blue crystalline limestone.

Another form of the rock is found in the oolite of Calne, which consists of alternations of hard shelly oolite used for flags, and soft, perishable, scarcely oolitic, limestone, workable by sawing parallel to the beds.

This form of the rock passes into the third or rubbly oolite, which is the most abundant variety in Wiltshire. This is a nodular rock with very indistinct stratification and much irregularity of texture, occasionally with ova three-tenths of an inch in diameter, constituting what is called pisolite.

In the deep pit through Kimmeridge clay on the line of the Wilts and Bucks Canal, this rock was very thin, scarcely oolitic, but chiefly a cellular mass of *caryophyllia* and *astræa*, and a similar character prevails in some quarries in the neighbourhood of Wootton Bassett. Below it the lower calcareous grit was in the state of loose sand.

Mr. Conybeare divides the coralline oolite near Oxford into two parts, of which the upper is a calcareous shure. freestone of close texture, full of comminuted shells, and irregularly oolitic or pisolitic. The beds are very thick, and the stone has been much used in buildings at Oxford, but is not found to be durable. The lower part is the true coral rag, consisting of two or three courses of nodular rubbly rock, very crystalline in aspect, and composed of masses of *astræa* and *caryophyllia*, with admixture of echinital and shelly fragments.

In Yorkshire the lower beds of the coralline oolite are in general exceedingly shelly, and full of *clypæus dimidiatus*, *clunicularis*, &c. and on the North side of the Val of Pickering, at Hackness, Ebberston, &c. are marked by an irregular bed of coral (*astræa*) and sponges. The middle part of the rock is regularly bedded with thin partings of clay, and very large vertical joints; the different beds vary much in the same quarry, from a soft, loose, whitish oolite to a solid rock with blue centres and large pisolitic spherules. At Malton it is more uniformly oolitic, and very full of *melania*, *trigonia*, *plagiostomata*, &c. and organic remains of all kinds. Near the upper part in the Aiton quarries is a bed of *caryophyllia* and echini, and the rock is crowned at Sunnington, Helmsley, &c. by a bed filled to excess with *trinitella* and *melania*. *Melania striata* and *trinitella* occur near the top of the rock about Brompton and Hackness, but at Malton they lie indiscriminately. *Ammonites* chiefly belong to the lower beds. About Kirkdale and Helmsley layers of obscurely defined nodules of bluish-grey chert, having the texture of sponges, lie in the lower part of the rock, and remind us of the silicious sponges of the Portland oolite.

These sections will show at once the general accordance of the characters of this irregular oolite, its variable thickness, and indefinite order of succession, circumstances which belong indeed more or less to all the oolitic formations. The corals which characterise the rock, lie very unequally, yet perhaps we may perceive a tendency to form two layers, one near the top, the other at the bottom of the rock. The Oxford series seems

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imperfect by the deficiency of the upper member, a circumstance probably connected with ancient denudations, by which also this rock has been greatly affected in different parts of Yorkshire.

Upper calc  
grit.

The upper calcareous grit, obscurely indicated at Weymouth, and very thin and unimportant in Wiltshire, (where it appears separated from the oolite by ferruginous clay,) is of considerable note along the North side of the Vale of Pickering, especially about Helmsley and Hackness. It then reaches even a thickness of 60 feet, and by intercalating its upper part with the Kimmeridge clay establishes a transition from the middle to the upper oolite formation. It is in general more ferruginous and less cherty than the lower calc grit, and in Yorkshire contains apparently fewer organic remains, but of the same kinds. It has been entirely removed by denudation from the oolite cliffs of the coast. At Weymouth its fossils are numerous and fine.

#### Upper Oolite Formation.

The upper or Portland oolite formation, consisting of limestone above and clay below, might be expected to occupy a country, whose physical geography should strongly resemble that of the district of coralline oolite. The area occupied by the calcareous group is indeed so very small in England, that little can be said on this point concerning it. Its commanding appearance in Portland Isle, in the Vale of Pewsey, at Swindon, and in the Vale of Aylesbury, is analogous to that of the oolite rocks in general, and the sands with which it is in some places associated, increase this resemblance.

Kimmeridge clay

The Kimmeridge clay in its much longer and more connected range in Dorsetshire, Wiltshire, Berkshire, and Buckinghamshire, (where it can be traced at least as far as Little Brickhill,) and beneath the sands of Lincolnshire, and through the Vale of Pickering in Yorkshire, presents the usual characters of a thick clay deposit, broad vales with a cold, stiff soil, without springs.

The Kimmeridge clay at its typical locality in the Isle of Purbeck appears in the cliffs, as a laminated clay, bluish or greyish-yellow, dividing spontaneously like other shales into large tabular masses, the joints often lined by calcareous spar. Layers of small argillaceous nodules occur. It passes gradually into a bituminous shale, imperfectly combustible, and finally into layers of brown shaly coal specific gravity 1.319, which burns with a smoky yellowish flame. Alum was formerly manufactured from these shales. The group is supposed to equal 600 feet in thickness. (*Geology of England*) In the Vale of White Horse at Evesham, it was penetrated by a well to the depth of 233 feet and the additional thickness of the incumbent beds in Swindon Hill being taken at only 70 feet, the stratum will appear 300 feet thick. Near Oxford it is only 100, and at Bagley Wood was found only 70. In Lincolnshire and Yorkshire its thickness generally appears much less through the unconformity of the chalk strata.

Near the bottom of the Kimmeridge clay in the Vale of White Horse, below the layers of ostrea delta, were found a band of coarse oolitic ironstone with fossils and layers of septaria, with ammonites, trochæ, and many other fossils much allied to those of the coralline oolite. Shale and bituminized wood were found at about the middle of the clay, and above this a course of thin balls of stone with mineral water. Near Weymouth the lower part of the clay contains, above large beds of

ostrea delta, beds of ferruginous impure calcareous grit, partially oolitic, and alternating with beds of red and green sand and blue clay containing ostrea delta. Small bands of calcareous grit may be seen in the lower part of the Kimmeridge clay of Yorkshire, below layers of ostrea delta. It thus appears that the remarkable species of oyster so named by Mr. Sowerby is a very characteristic fossil of the lower parts of this clay group, and its manner of occurrence is equally so. For whether in Yorkshire, at Helmsley, Kirby Moorside, Elloughton, &c. in Lincolnshire at Market Rasen, at Little Brickhill in Buckinghamshire, at Heddington near Oxford, at Evesham and Pewsey Vale in Wilts, or at Weymouth, and we may add, at Havre, it always appears in broad continuous floors, parallel to the planes of stratification, the valves usually together, with young ones occasionally adherent to them, and entirely imbedded in clay, without nodules or stones of any kind, and without any other organic remains in the layers.

The upper oolite group consists, like those previously described, of a variable mass of sand and sandstone concretions, surmounted by a partially oolitic, shelly limestone. Were the rock to be seen more completely it is probable that it would also show a less definite arenaceous zone above. In Purbeck it is covered by the fresh-water or Wealden formation, and in Wiltshire, Berkshire, and Buckinghamshire by the green sand.

The varieties of composition in the limestone are such as have been noticed for the other oolites, viz. fine-grained white oolite, loose granular limestone of earthy aspect, and compact micaceous limestone with conchoidal fracture.

In the Island of Portland the groups present, according to Mr. Webster, (*Geological Transactions*), the following characters.

	Stone brash, a cream coloured limestone	feet.
Upper beds	Parting of the same with black clay	1
	Cap stone, in three layers, with partings of clay, cream coloured and hard, so as to turn the points of the tools.	10
	Roach, a rock composed of fragments of oyster shells, cemented together	6
Middle beds	White beds, marked table stone	5
	Layers of flint and stony rubbish	6
	Middle bed, marked table stone, with few marine impressions	5
	Parting stone with shells of no value	2
	Third bed with few shells, generally the most saleable freestone	7 to 14
Lower beds	Many layers of flints and of unserviceable stone	50 to 60

Still lower, according to Dr. Buckland and Mr. De la Beche, is a bed of sand and sandstone 60 feet thick, with green grains, and very like to the lower green sand.

At Chicks Grove, in the Vale of Salisbury, Wilts, the series of limestones, more or less associated with sand, especially in the lower part, reaches more than 60 feet in thickness. Miss Bennett, who has extracted so many treasures from those quarries, has given a minute section of the beds.

The five upper beds, amounting to 29 feet, consist of white limestone, locally called chalk, with one interposed layer of bad shelly stone, and a band of cherty flint 4 inches thick. The middle bed of this limestone, 2 feet thick, is excessively rich in shells, but the thicker beds above and below contain none.

The next three beds of the quarry, amounting to 10 feet, consist of sandy limestones, with fragments of shells.

Five beds below consist of sandy limestone, mostly compact and shelly, with grains of green sand in greater or less abundance.

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The three lowest beds are composed of loose sandy limestones, with more or less of the green grains before noticed, shells and fragments of shells.

The shells most abundant at Chicksgrove are trigonia, pectines, ammonites, uniones, trochi, &c.

Brill, &c.

The imperfect sections at Brill Hill and Garsington present several points of analogy with the above section, especially in the presence of the cretaceous bed, and the quantity of sand below the calcareous part of the rock is well seen here and at Shotover, where it encloses in the lower part large, grotesque, concretionary blocks of sandstone, sometimes full of shells, and generally abundant in green grains.

Abundance of green grains accompany these lower beds in their course through the Vale of Aylesbury, and are also recognised at Swindon.

The height of the ground occupied by the detached portions of the upper oolite group is considerable in Brill Hill, (780 feet,) in Shotover amounts to 500 feet, at Swindon probably 400 feet, in Portland 300 feet, but in the Vale of Pewsey it is very low.

Part bed of  
Portland.

One of the most interesting observations concerning the circumstances which intervened between the marine deposits of oolite and the fresh-water or estuary deposits of the Purbeck clays and limestones, is that of Dr. Buckland and Mr. De la Beche on the *dirt bed* which lies between these groups of strata in the Isle of Portland. This bed is compared by those acute Geologists to black vegetable mould. The stems of cycadeæ and larger coniferæ which are found in this bed, often "stand erect, and have their roots attached to the black soil in which they grow;" thus presenting us with an ancient submerged forest, for comparison with the more modern submarine forests which in so many points margin the English, Welsh, Scotch, and Irish coasts.

It is concluded by these authors that the Portland rock, wherein these plants are stated to be in the place and attitude of growth, had been raised to become dry land, and then sunk again, under such circumstances as to become covered by fresh water, which produced the Purbeck limestones and clays; and it appears a matter of probable inference that at the same periods the whole Wealden district was submerged under nearly the same circumstances. The absence of conglomerates and dislocations appears to prove that these submersions were effected quietly and gradually; certain beds of oysters show that the waters were at least occasionally brackish, the sea again regained its dominion, and deposited the cretaceous rocks and marine testacea, and finally yielded place again to a lacustrine deposit.

#### Wealden Formation.

Until the appearance of Mr. Mantell's Works on the Geology of Sussex, the peculiar relations of the vast thickness of sandstones and clays of the interior of Kent, Sussex, and Hampshire, were entirely misunderstood. No one supposed that these immense strata were altogether of a peculiar type, and interpolated amidst the rest of the marine formations, as a local estuary formation, of which only very faint traces can be perceived in other parts of England. Always striving to make particular results harmonize into one general system, Mr. Smith and other Geologists at one time referred the interior sandstones to the "iron sand," and the Weald clay to one of two beds, confused under the title of oak-tree clays. This mode of classification seemed, indeed,

tolerably consistent with the mineralogical characters of the formations, but was found wholly at variance with their animal and vegetable remains. For these, instead of being fossils of the iron sand and Kimmeridge clay or Gault, were really a peculiar suite of terrestrial and fluviatile exuvie of which very few traces have been perceived elsewhere.

Mr. Mantell's publications have clearly shown that the true place of the whole Wealden formation is *below* the iron sand or lower green sand, and, probably, immediately *above* the Purbeck limestones, which overlie the Portland oolite.

The only places in England where analogous beds are known to occur, are at the back of the Isle of Wight, in the Isle of Purbeck, along the South side of the Dorset Downs, and in the Vale of Tisbury in Wilts.

The Wealden formation naturally divides itself into two groups, which give distinct physical features to the Countries which they occupy; and if to these we add the Purbeck limestones below, we have the following order of succession.

Groups of  
the Wealden  
formation.

Upper group.	{ Pale blue clay, of considerable but variable thickness, having in the upper part septaria of argillaceous ironstone, and in the lower part beds of the shelly limestone, called Sussex marble.
Weald clay.	{ Fawn-coloured sand and friable sandstone. (Horsham beds.)
	{ Calcareous sandstones, alternating with friable and conglomerate grits, resting on blue clay. (Tilgate beds.)
Middle group.	{ White sand and friable sandstone, alternating with clay. (South sandstone.)
Hastings sands	{ Bluish-grey limestone alternating with blue clay and sandstone shale, and some beds of calciferous sandstone. (Ashburnham beds.)
Lower group.	{ The Purbeck beds, consisting of shelly limestone alternating with clay.

The Weald clay forms one general valley, most conspicuous on the Northern side, between the elevated central ridges of the Hastings sands, and the chalk downs of Kent, Surrey, Hampshire, and Sussex, from Hythe by Tunbridge, Hartingcombe, Hailsham, to Pevensey.

The Hastings sands distinguish themselves by forming a central axis of elevation along what is called the Forest ridge, by Battle, Crowborough, and Tilgate Forest to Horsham; Crowborough, the highest point, is 804 feet above the sea. This arrangement may be studied on Mr. Mantell's and Mr. Smith's sections, but the general axis of elevation is so confused by a number of local disturbances, and is, moreover, so broad a ridge, that its character is often overlooked. Those who suppose the chalk of the Northern and Southern escarpments to have once extended over all the area of the Wealden formation, and to have been subsequently removed by watery violence, have rightly applied to this devastated region, the name of the great denudation.

Whether, in truth, the Purbeck beds should be thus ranked in a separate section, or be considered as the equivalent of the whole argillo-calcareous formation of the Weald, is, perhaps, matter of doubt. It is, however, certain that the most decided analogy prevails between the upper part of the Purbeck series and the marble beds of the Weald clay. We shall now add a few details on these groups in succession, beginning with the Purbeck beds.

These consist of many thin strata of argillaceous Purbeck limestone, alternating with slaty marls, and form an aggregate of 300 feet in thickness. Mr. Webster de-

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describes the beds of stone as consisting chiefly of shells, usually, but without certainty, referred to the fresh-water genus *paludina*. They might, with equal confidence, perhaps, be supposed to belong to an ancient littoral genus of the family *turbinacea*. But a small portion of these calcareous beds is fit for columns, chimney-pieces, and other architectural uses for which the "Purbeck marble" is celebrated. Our cathedrals were formerly supplied from quarries in the very highest part of the series, which are now extinct. The shells in this stone are usually *small* paludiniform shells. According to Mr. Middleton, three *veins* of good stone, not exceeding altogether 17 feet, lie in the midst of alternations of other stone compact or shelly, and black slaty clay, more than 270 feet thick.

Ashburn  
ham beds.

The Ashburnham beds, above 100 feet thick, consist of shelly limestone and shale, alternating with blue clay, and containing subordinate beds of nonstone and sandstone. Limestone, of a dark bluish grey colour, full of immense quantities of bivalve shells, more or less spathose, is the most characteristic deposit of the group. The shale which is associated with this limestone, sometimes contains the same shells in a white friable state. In ancient times the rich ironstone accompanying this limestone was, through the use of the latter as a flux, converted into iron by wood fires, and thus, in part, have the vast forests of Sussex been diminished. The shells are usually supposed to belong to *cyrena* or *cyclus*, in accordance with the opinion that the whole Wealden formation is of fluviatile or estuary origin, but this is still an obscure point, and some of the shells appear to resemble *nucula*. At Poundsford a bed of calciferous Tilgate sandstone is found *under* a bed of the Ashburnham limestone, and the same was found in some of the limestone pits of Lord Ashburnham.

Worth  
sands.

The Worth sands and sandstones afford a fine building-stone extensively dug at Worth, near Crawley. The sandstone is for the most part of a white or pale fawn or yellow colour, and occasionally contains leaves and stems of ferns, arundinaceous plants, and other vegetable reliques. They may be well studied in the cliffs near Hastings.

Tilgate  
beds.

The Tilgate beds consist of three divisions. The lower one is clay or marl, of a bluish-grey colour, alternating with sand, sandstone and shale, and containing stems of vegetables, and very rarely bones and shell.

The middle division consists principally of large concretionary or lenticular masses of a compact calcareous grit, or sandstone lying in sand. The stone is fine grained, of a light grey colour, inclining to blue or green, and is composed of sand, cemented together by about 25 per cent of crystallized carbonate of lime. Its fractures frequently show glistening faces. The lower portions of this bed form a conglomerate, and contain pebbles of quartz and jasper, sometimes *evidently* water-worn. (Of this stone are three or four layers, from 2 or 3 inches to 1½ or 2 feet, associated with sand.) The surface of the blocks is often covered with mammillary concretions. These are the strata from which Mr. Mantell has drawn the astonishing profusion of animal and vegetable remains. The vegetables are wholly of terrestrial origin, mostly of cryptogamous and gymnospermous structure. There are probably no zoophytic remains. The testacea (mostly casts), much resemble the lacustrine genera, *paludina*, *unio*, *cyrena*. Fish-teeth and scales abound, with remains of a land tortoise, a fresh-water and a marine turtle, plesiosaurus, cro-

codile, megalosaurus, hylasosaurus, iguanodon, and some kinds of aquatic birds.

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Irregular alternations of sand and sandstone, of various shades of green, yellow, and ferruginous, the surface often furrowed like the sand on the sea-shore, cover the whole group.

The Horsham beds of sand and friable sandstone, grey, yellow, or ferruginous, with occasional interspersions of ironstone, and a very large proportion of disseminated small linear portions of lignite, form the upper division of the Hastings group, and encircle the immense Tilgate beds. The sandstone is micaceous and ferruginous, and sometimes holds a considerable proportion of calcareous matter. These beds alternate with a stiff grey loam or marl. The lignite is conjectured to have been derived from carbonized ferns.

The Weald clay group, besides its general physical features already mentioned, has little to detain us. The septaria of this clay are composed of a deep red, argillaceous nonstone, and with remains of fishes and cyprides, occur in layers of two or three feet in thickness in the upper divisions of the clay. The shelly limestones, so well known by the name of Sussex marble, appear to occupy chiefly the middle beds of the Weald clay. They occur in layers of a few inches or a foot in thickness, separated from each other by seams of clay or coarse friable limestone. The compact varieties, when polished, exhibit sections of the enclosed shells. These are usually referred to *paludina*, and have been compared to the recent *paludina vivipara*, and they are associated with the shelly remains of a minute branchiopode, (*cypris*?) from which circumstance it is inferred that the Weald clay is a lacustrine deposit. This shelly marble occurs all along the line of the Weald clay from Leighton to Petworth, Newdigate, South of Tilvester hill, and Bethersden in Kent. *pot mida* and *cyrena* have been collected from this clay.

The evidence upon which it is now very generally admitted that the Wealden formation was a fresh-water or estuary deposit, is founded upon a contemplation of the organic remains, and this subject admits of three general observations.

*First* There is in all the strata of the Wealden formation whether sandy, argillaceous, or calcareous, an almost entire absence of decided marine genera of shells and zoophyta. In particular, the numerous and characteristic tribe of ammonites and belemnites, of trigonia, terebratula, and ostrea, of celmida stellenda, and polyparia, are entirely absent, a circumstance certainly unparalleled in any section of equal variety among marine strata.

*Secondly* What shells there are have most generally the forms of fresh-water or littoral genera, and it may be remarked especially that this kind of evidence bears with most force upon the middle group.

*Thirdly* The plants which abound in this middle group are of terrestrial, or marshy, and not of marine origin, and the saurian remains also indicate the littoral, or marshy life of those monstrous animals.

We may therefore confidently adopt Mr. Mantell's conclusion of the fresh water origin of the materials of the Tilgate beds, and suppose these materials to have been deposited in an estuary by one or many rivers; and also refer to a similar place of deposit, the lower bed of limestone and clay, and the upper group or Weald clay; but that the materials of these argillo-calcareous deposits were also derived from the land is not yet proved in the same manner as has been done for the

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arenaceous-calcareous deposits of the forest ridge. Whatever may have been the causes, it is probable that the change from the *truly marine* Portland oolite to the supposed *lacustrine* Purbeck beds is *gradual*, and the same must be said of the change from the Weald clay to the lower green sand. The varying force with which the water-floods of the land were introduced into the supposed estuary or gulf, may, perhaps, explain both gradations of the extreme groups and the determined fresh-water origin of the middle group of the Wealden formation.

#### Oolitic System — Foreign Localities

large and  
extensive.

The oolitic system is so largely developed in England as to form a very conspicuous if not the principal feature in its Physical Geography, and its extreme ramifications reach the Northern and Western coasts of Scotland and the Eastern shore of Ireland. But the range of these rocks is still more extensive on the Continent of Europe, and obscure indications of the continuation of the lower formation has been in North America and are repeated in India. In France a broad belt of oolitic rocks borders on the East the primary rocks of Brittany and La Vendée, and wepters and the basin of Paris from the coast of Normandy (Calvados) by Falaise, Alençon, Le Mans, Saumur, Poitiers, Châteauneuf, and Nevers, and through Burgundy, Franche-Comté, and Lorraine till along a line from Avesnes to Luxembourg, it but ceases at the slate mountains of the Ardennes. From Poitiers the oolites continue themselves Westward to La Rochelle, Southward to Angoulême, Périgueux, Cahors, and the county of Montauban. A little discontinuity here occurs, but the crests of Rhodéz and the Cévennes mountains by continuing themselves South Westward to Montélimar, Cuesco, and Foré, along the Northern slope of the Pyrenees to Fontarabie, and North Eastward to Mende, and Grenoble, and so to the Jura, and South Eastward to Marseilles and Nice, unite into one irregular mass the whole area of the French oolite. These formations are largely developed in Spain, and in particular form a band on the slope of the Pyrenees.

Along the Swiss border of France runs the local calcareous chain of the Jura, and the whole northern region is a mass of the oolitic rock. It is therefore generally assumed on the Continent a type of the system, and the terms *Jurakalk*, *Jurakalkstein*, are exactly equivalent to our oolitic system. This is connected below the alluvial valley of the Rhone with the oolites of Burgundy. In its continuation Northward the Jura ranges pass in a broad belt through Württemberg, Bavaria, and Franconia, and reach the Main, as it issues from the Bohemian mountains.

The Jura is also connected by crossing the Rhone below Geneva, with the limestone which follows the range of the Western Alps from Provence through the Tarentaise and Savoy into the Valais, and continues along the Oberland mountains, across the Lakes of Thun, Brienz, Lucerne, and Willenstadt, and then beneath the Tyrolean and Styrian Alps by Inspruck and Salzburg, to the neighbourhood of Vienna. Nor is this the end of the enormous range, for the Northern border of the Carpathians about Cracow and Dynow is defined by vast breadths of compact oolite.

On the Southern side of the Alps, the same limestones appear in great force, and stretch through Illyria and

Carniola to Trent, and the Lakes Garda, Isèo, Como, Lugano, and Maggiore.

Besides these immense ranges of rocks of the oolitic area, many smaller detached portions may be seen upon Von Buch's and other Maps, and one in the Northern part of France, around Boulogne, is of particular interest.

It appears, then, that the sea which deposited the oolites floated round, or perhaps covered the spaces where now rise on high the Alps, the Carpathians, the Pyrenees, Auvergne, the Vosges, the Black Forest, and Bohemian mountains, in general corresponding to the basin in which the saliferous system was formed. The original arrangement of the rocks has been in places immensely disturbed, and vast regions have been devastated by floods, yet no doubt the general geographical outlines of the system are nearly what they always were. It may not be easy always in the present state of knowledge concerning the extent of subterranean movements, to say what were the depths and the shallows of this great ocean, but even toward this very considerable approximation may be made by comparing the mineral and zoological and botanical characters of the deposits in different places.

Notwithstanding their vast extent, it does not appear that the continental oolites are any where subject to the greater variation and composition than the English series.

In the North of France most of the groups acknowledged by the English Geologists may be recognised, as the *bas inferior oolite*, Bath oolite, *forest marble*, Oxford clay, *coralline oolite*, *Kimmeridge clay*, and even the Portland oolite (*De la Beche tract Trans*) and the original remains are either very similar or identical. But in the vicinity of the *fontaines* of Auvergne it is difficult to distinguish more than the *bas*, and one great overlying mass of oolites indistinctly divided, except by having in the lower part a ferruginous bed sometimes accompanied by ferruginous, and probably corresponding to that of the inferior oolite.

The Jura shows us distinctly the *bas*, and a mass of calcareous rocks, sometimes perfectly oolitic, in other places earthy or compact, occasionally interlaminated with clay, but hardly capable of any clear and satisfactory division. The lower parts are often ferruginous and sandy, and clearly represent the inferior oolite. The upper parts, nevertheless, by admixture of chloritic grains and beds of green sand, appear to represent the upper oolite series of England until as may be particularly observed in the *Saône*, it is difficult not to allow that the oolitic and cretaceous systems are united in the cap beds of the *Jurakalk*. This should be compared with the previous notices of green sand below the Portland oolite. The *facoid* grits along the line of the Eastern Alps clearly belong to the green sand, and the relations of the *hippurite* limestone which is at the top of the alpine *kalkstein* shows that the causes which in England and the North of France have occasioned such decided differences in the oolitic series, and established so many groups, did not obtain in these parts. It is extremely probable that this is merely the difference between littoral and pelagian deposits. In England, generally, the disturbance of a shore is indicated by the more numerous alternations, beds of clay and sandstone, rolled shells, ripple marks, and land plants, and, where these characters go to extreme, the whole formations appear changed to a coal system. Something like this

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happens, as before mentioned, at the Porta Westphalica, but the greater part of the oolitic limestone of France, Germany, and the Alps, appears to have been deposited in deeper and more quiet waters. Through all these Countries the proportion of limestone to the more mechanical deposits is much greater than the average of the English series, the marks of disturbance are mostly wanting, the lines of division are obliterated, and the products of the land infrequent. Perhaps we may in this way account for the smaller number of organic remains belonging to the Alpine limestones, for if these were eminently pelagian, they should probably contain fewer marine exuviae, since we have good reason to believe that the deepest parts of the sea, where light can hardly penetrate, and all is dull repose, are almost devoid of organic life. As the borders of a Desert are rich in every vegetable hue and resonant with all the voices of animals, so are the borders of the sea prolific of existence, but the Sahara and the Ocean are equally dead at their centre.

The oolitic texture seems to lose itself in the same manner toward the Alps, amongst which it can be seldom seen, and in general the paucity of organic remains is greatest in the most compact or most crystalline of the varieties of these limestones. The Jura, through its whole range in Wurtemberg and Bavaria, uniformly shows upon the surface a cap of rocks associated with sand, and often passing upwards into ferruginous oolite, and the same thing happens above the lias of Hanover and Westphalia.

Solenhofen  
beds.

In the centre of the German Jura, at Solenhofen and Eichstadt, occur beds of white fissile limestone, now universally employed in lithography, which abound in organic remains and have been long supposed to be much related to the Stonesfield slate. This relation is, perhaps, not supported by their Geological position, for this is certainly above not only the inferior oolite previously described, but also above a considerable thickness of Jura-kalk, and a variable mass of dolomite. M. Von Dechen appears to think these beds of an anomalous character, as indeed their organic remains testify. The whole of this slaty group is seen to thin out near the mouth of the Altmühl between masses of dolomite, being entirely surmounted by green sand and cretaceous deposits (Murchison, *Geol. Proceedings*). The author just quoted inclines to the opinion that the higher members of the oolitic groups of England, have not yet been satisfactorily defined in any part of central Germany. This subject will be soon cleared up by the active and intelligent Geologists of Germany.

#### *Disturbances of the Oolitic System*

The parallelism of beds over large regions, the repetition of similar rocks at frequent intervals, and the gradual change of the species of organic remains through the whole series appear to indicate that the long period when the oolitic system was deposited was one in which the ordinary operations of Nature were uninterrupted by paroxysms of igneous violence. On viewing the whole series of these strata and considering the manner in which their outcrops follow one another, it appears that only a very few instances can be pointed out where any beds of the oolitic system are really unconformable to others of the same system below them. Apparent exceptions to this law are indeed presented by every detailed Geological Map, particularly in the case of the coralline oolite, but this rock

appears to have been an irregular and limited deposit. It is, perhaps, hardly enough to justify the term unconformity, to show that some of the upper beds of this system have probably been removed by wasting effects of water before the deposit of the incumbent clay, as at Heddington. One case, however, may be mentioned, at Cave, in Yorkshire, where, amidst the more striking phenomena of unconformity between the oolitic system and the chalk, there appears reason to believe that the deficiency in conchoidal and forest marble systems may be ascribed to a local unconformity of the stratification of the Kelloway rock. Other instances will no doubt be discovered, but they will probably be found equally unimportant.

The case, however, is entirely different when we transport ourselves to the period immediately following the deposit of the oolites. Through a large part of England the line of the outcrop of the chalk, green sand, &c. follows pretty exactly the range of the oolitic system, and of course we must infer that for all those districts the bed and boundary of the sea were not at all changed in position in the interval between the two systems of strata. But at other extremities of the range the plane of the cretaceous system is carried over the edges of the oolites from the upper to the lower part of the system, so that at Bishop Winton, in Yorkshire, it rests within 25 feet of the top of the red marl.

In Dorsetshire, the chalk and green sand by over extension rest on all the members of the oolite in succession, and at length, in Haldon, actually touch the red marl.

Mr Murchison, from his interesting observations on the Ord of Caithness, inferred that this granitic mass had been upheaved in a solid form, and thus that the contiguous or neighbouring oolitic strata were broken up. The brecciated character so frequent in these limestones is referred to a subsequent recomposition of the fragmented parts. Without dwelling on other cases in the British dominions, we may fairly infer from this important observation, coupled with the former cases, that there was an extensive disturbance and angular movement in the interior of the Earth beneath the Sea in which the oolites had been deposited. Considerable faults, ranging East and West, accompany the elevation of the oolites in Yorkshire.

On the Continent very extensive disturbances, happening at the same era, show that this was indeed a period when the convulsive energies of the subterranean regions were strongly and extensively exerted.

To this period M. Elie de Beaumont refers a very extensive line of dislocations, connected with the elevation of Mont Pilat near Lyons, the Côte d'Or, and the Erzgebirge. It is observed that all these axes of elevation range North Eastward and South Westward, and in the regions intermediate between these, marking ridges and lines of undulated stratification may be traced in the same North-Eastern and South Western direction, particularly on the broad belt of the Jura.

Without insisting upon the exact parallelism ascribed by M. de Beaumont to these lines of disturbance, we are warranted in admitting that to the convulsions at this period, the long range of oolites connected with the ridges of the Jura both in France and Germany, and with the line of the Erzgebirge, owe, if not their actual height above the sea, some of their peculiar physical features. The cretaceous system in the vicinity of these lines of disturbance appears to be unaffected by them, except by the new outlines which were then given to

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the embosoming ocean, from which at a later period the chalk, green sand, &c. were deposited.

The oolites which pass North-Westward from Lorraine are probably continuous under the whole of the chalky plains of Picardy, but their superficial outcrop is extinguished by the overextension of the chalk to contact with the slates of the Ardennes, nor is it renewed on the Northern side of those mountains. Yet this case may not happen through any unconformity, but be a

consequence of the irregular bed of the ancient sea. Thus, the red sandstone may be covered and concealed by the oolite, and the latter may be hidden below the chalk, and yet there may be no unconformity. This view is supported by the successive coming out in proceeding to the South-East from Avesnes, first of the oolite, then of the keuper, muschelkalk, and red sandstone, from their abutments against the older slates.

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### Table of Organic Remains in the Oolitic System.

N. B. The different oolitic formations are designated, where known with certainty, by the letters *l*, *m*, and *u*, (lower, middle, upper,) attached to the several localities.

### PLANTS. (The names chiefly from Brongniart.)

Family.	Name.	British Localities.		Foreign Localities.	
		In Lias.	In Oolites.	In Lias.	In Oolites.
Algæ . . . .	Fucoides furcatus . . . . .		Stonesfield, <i>l</i> .		
	Stocki . . . . .				Solenhofen.
	encelloides . . . . .				Ditto.
	undescribed . . . . .	England.			
Equisetacæ.*	Equisetum columnare . . . . .		Whitby, <i>l</i> . Bror, <i>l</i> .		
	laterale, Phil. . . . .		Scarborough, <i>l</i> .		
Filices . . . .	Glossopteris Nilsoniana . . . . .			Hér.	
	Phillipsii . . . . .		Ditto, <i>l</i> .		
	Pecopteris Agardhiana . . . . .			Ditto.	
	polypodioides . . . . .		Ditto, <i>l</i> .		
	denticulata . . . . .		Ditto, <i>l</i> .		
	Phillipsii . . . . .		Ditto, <i>l</i> . Collyweston, <i>l</i> .		
	Whitbyensis . . . . .		Yorkshire coast, <i>l</i> .		
	Norbeusii . . . . .			Bornholm, <i>l</i> .	
	tenuis . . . . .			Ditto, <i>l</i> .	
	Pingetii . . . . .			Ditto, <i>l</i> .	
	Regier . . . . .			Mamers, <i>l</i> .	
	Desnoyersii . . . . .			Ditto, <i>l</i> .	
	recentior, Phil. . . . .		Scarborough, <i>l</i> .		
	exilis, Phil. . . . .		Ditto, <i>l</i> .		
	caespitosa,* Phil. . . . .		Ditto, <i>l</i> .		
	eristata, Phil. . . . .		Ditto, <i>l</i> . Egton, <i>l</i> .		
	Neuropteris lobulosa, Phil. . . . .		Scarborough, <i>l</i> .		
	Sphaeropteris hymenophylloides* . . . . .		Stonesfield, <i>l</i> . Whitby, <i>l</i> .		
	crenulata . . . . .		Whitby, <i>l</i> .		
	denticulata . . . . .		Ditto, <i>l</i> .		
	Williamsoni . . . . .		Ditto, <i>l</i> .		
	macrophylla . . . . .		Stonesfield, <i>l</i> .		
	muscoides, Phil. . . . .		Yorkshire coast, <i>l</i> .		
	digitata, Phil. . . . .		Stonesfield, <i>l</i> . Whitby, <i>l</i> .		
	Tæniopteris latifolia . . . . .		Ditto, <i>l</i> . ditto, <i>l</i> .		
	*vittata . . . . .		Whitby, <i>l</i> .	Ditto.	
	Pachypteris lanceolata . . . . .		Scarborough coast, <i>l</i> .		
	ovata . . . . .		Ditto, <i>l</i> .		
	Filicites Bechei . . . . .			Bornholm, <i>l</i> . Helsing- bourg, <i>l</i> .	
	Cyclopteris digitata, Lind. . . . .		Scarborough, <i>l</i> .		
	Beauvi, Lind. . . . .		Ditto, <i>l</i> .		
	auriculata . . . . .		Ditto, <i>l</i> .		
	Clathropteris meniscioides . . . . .			Ditto . . . . .	Vosges.
	(Phyllites nervulosus, Phil.) . . . . .		Ditto, <i>l</i> .		
Lycopodiaceæ.	Lycopodites patens . . . . .			Ditto.	
	Williamsoni . . . . .		Ditto, <i>l</i> . Whitby, <i>l</i> .		
	falcatus, Lind. . . . .		Whitby, <i>l</i> .		
Cycadeæ . . . .	Pterophyllum Williamsoni . . . . .		Whitby coast, <i>l</i> .		
	complanatum, Phil. . . . .		Scarborough coast, <i>l</i> .		
	minus . . . . .		Scarborough, <i>l</i> .		
	Nilsoni . . . . .		Whitby, <i>l</i> .		
	dubium . . . . .			Ditto.	
	majus . . . . .			Ditto.	
	Zamites Bechei . . . . .	Lyme Regis		Mamers, <i>l</i> .	
	Bucklandii . . . . .	Ditto		Ditto, <i>l</i> .	
	lagotis . . . . .			Ditto, <i>l</i> .	
	hastata . . . . .			Ditto, <i>l</i> .	
	Zamia pectinata . . . . .		Stonesfield, <i>l</i> .		
	patens . . . . .		Ditto, <i>l</i> .		
	longifolia . . . . .		Scarborough, <i>l</i> .		
	penniformis . . . . .		Ditto, <i>l</i> .		
	elegans . . . . .		Ditto, <i>l</i> .		



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			In Lias.	In Oolites.	In Lias.	In Oolites.
Cycadææ	Zamia Goldieæ	acuta		Scarbofough, L.		
		lavis		Ditto, L.		
		Youngii		Ditto, L.		
		Feneonis				Seysael, L.
		Mantelli				Ditto, L.
		pecten				Ditto, L.
		Nilsonia brevis			Hör.	
		elongata			Ditto.	
		Cycadeoidea magalophylla, } Brown		Portland, u.		
		microphylla, B.		Ditto, u.		
	Coniferae	Taxites podocarpoides		Stonesfield, L.		
Bachyphyllum mammillare			Whitby, L.			
Thuytes divaricata			Stonesfield, L.			
expansa			Ditto, L. Collyweston, L.			
acutifolia			Stonesfield, L.			
cupressiformis			Ditto, L.			
Coniferæ of uncertain tribes..		Whitby, &c.	{ In lower, middle, and upper oolites.			
Monocotyle- douræ	Bucklandia squamosa			Stonesfield, L.		
		Flabellaria viminea		Whitby coast, L.		
		Culmites Nilsoni			Ditto.	
Of uncertain tribes	Mammillaria Desnoyersii				Mamers, L.	

The Valorsine and Tarentaise slaty rocks, supposed by Elie de Beaumont to be of the age of lias, contain plants of the carboniferous epoch. If the Geological situation of these rocks be rightly determined, we must conclude that certain tribes of plants which flourished in the carboniferous epoch, existed in the vicinity of this deposit, under some peculiar circumstances, through the whole of the new red sandstone period, and were finally extinguished at the commencement of the oolitic era. These plants are in a singular state of conservation, the vegetable substances being replaced by talc—perhaps as an effect of the igneous agency exerted in elevating the Alps, which is most remarkably exhibited in the granite veins and interposed masses of the Valorsine. The lias along the Alpine chain is frequently prismatized and converted into a kind of slate.

## POLYPARIA.

N. B. The lias contains very few traces of Polyparia. Anthophyllum sessile is described by Goldfuss from "the upper part of the lias," Thurnau.

Family	Name.	Upper Jura limestone of Württemberg, Bavaria, Switzerland, &c.
Fibrosa	Achilleum dubium	Solenhofen.
	cheirotomum	Streitberg.
	muricatum	Ditto.
	tuberosum	Hatthelm.
	cancellatum	Ditto.
	costatum	Streitberg.
	Manon peiza	Ditto.
Seyphia	marginatum	Baireuth.
	impressum	Muggendorf.
	cylindrica	Streitberg.
	elegans	Thurnau.
	culopora	Ditto.
	texturata	Giengen.
	* costata	Baireuth.
	verrucosa	Chaumont, Streitberg.
	textata	Legerberg.
	cariosa	Passau.
	polymorpha	Streitberg.
	clathrata	Ditto.
	milleporata	Baireuth.
	parallela	Streitberg.
	psilopora	Muggendorf.
	obliqua	Ditto.
	rugosa	Streitberg.
	tenuistria	Ditto.

Familv.	Name	Upper Jura limestone of Württemberg, Bavaria, Switzerland, &c.
Fibrosa	Seyphia articulata	Muggendorf.
	pyriformis	Streitberg.
	punctata	Ditto.
	radiciformis	Ditto.
	reticulata	Ditto.
	dictyota	Ditto.
	procumbens	Baireuth.
	paradoxa	Amberg, Streitberg.
	empleura	Streitberg.
	stricta	Ditto, Muggendorf.
	Munsteri	Streitberg, Ratibon.
	propinqua	Streitberg.
	cancellata	Ditto.
	decorata	Muggendorf.
	Humboldtii	Ditto.
	Sternbergi	Streitberg.
	Schlottheimii	Streitberg, Thurnau.
	secunda	Streitberg.
	verrucosa	Ditto, Wargau.
	Bromii	Baireuth.
	intermedia	Hatthelm.
Tragos	Neesii	Streitberg.
	* turbinata	Ditto.
	* clathrata	Ditto.
	cellulosa	Onabruck, Ortenberg.
	pezizoides	Muggendorf.
	* acetabulum	Streitberg, Randen.
	patella	Randen, Siegmaringen.
	spherioides	Württemberg.
	tuberosum	Rabenstein.
	radiatum	Streitberg.
	rugosum	Ditto.
	reticulatum	Ditto.
	verrucosum	Ditto.
	tuberosum	Baireuth.
Cnemidium	lamellosum	Randen.
	stellatum	Ditto.
	striatopunctatum	Ditto.
	rimulosum	Ditto.
	mammillare	Streitberg.
	rotatum	Thurnau.
	tuberosum	Caen.
	granulosum	Streitberg.
	astrophorum	Hatthelm.
	capitatum	Amberg.
Siphonia pyriformis		Chaumont.
Myrmecium hemisphaericum		Thurnau.

The preceding catalogue of fibrous polyparia, extracted from Goldfuss, (*Petrefactenkunde*), contains, probably, many species which further research will iden-

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tify in England. All of them, except when the localities are marked *l.*, are to be referred to the upper or middle oolite. All the ascertained British species are comprised

in the following singularly short list, which we will venture to say ought to be decupled.

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*Spongia floriceps*, Phil. . . . . Yorkshire. . . . . In middle oolite.  
*clavarioides*, Lam. . . . . Wiltshire. . . . . Ditto.  
*Alcyonium* ? . . . . . Ditto. . . . . Ditto.

Family.	Name.	British Localities.	In the Oolites of Würtemberg, Bavaria, France, &c.
Corticifera . . . . .	<i>Isis</i> , Park. . . . .	Calne, <i>m.</i>	
Cellulifera . . . . .	<i>Cellepora orbiculata</i> . . . . .		Streitberg.
	<i>echinata</i> . . . . .		Haute Saone, <i>l.</i>
	<i>Coscinepora sulcata</i> . . . . .		Switzerland.
	<i>Retepora</i> . . . . .	Yorkshire, <i>l.</i>	
	<i>Flustra</i> . . . . .	Wiltshire, <i>l.</i>	
	<i>Ceriopora radiceiformis</i> . . . . .		Thurnau.
	<i>*dichotoma</i> . . . . .		Ditto.
	<i>*clavata</i> . . . . .		Ditto.
	<i>striata</i> . . . . .		Ditto, Streitberg.
	<i>angulosa</i> . . . . .		Thurnau.
	<i>alata</i> . . . . .		Ditto.
	<i>crispa</i> . . . . .		Ditto.
	<i>fusosa</i> . . . . .		Ditto, Streitberg.
	<i>radiata</i> . . . . .		Thurnau.
	<i>compressa</i> , Mun. . . . .		Ditto.
	<i>orbiculata</i> . . . . .		Haute Saone, <i>l.</i>
	<i>Aulopora compressa</i> . . . . .		Rabenstein, Grafenberg, <i>l.</i>
	<i>intermedia</i> , Myl. . . . .		Streitberg.
	<i>decipiens</i> . . . . .		Buxweiler.
	<i>dichotoma</i> . . . . .		Streitberg.
	<i>Entolophora cellarioides</i> , Lam. . . . .		Normandy, <i>l.</i>
	<i>Spiropora tetragona</i> , Lam. . . . .		Caen, <i>l.</i>
	<i>crispata</i> , Lam. . . . .	Wiltshire, <i>l.</i>	Normandy, <i>l.</i>
	<i>elegans</i> , Lam. . . . .		Ditto, <i>l.</i>
	<i>utricata</i> , Lam. . . . .		Ditto, <i>l.</i>
	<i>Eunomia radiata</i> , Lam. . . . .	Bath, <i>l.</i>	Ditto, <i>l.</i>
	<i>Claytonia clamecedinus</i> , Lam. . . . .	Wiltshire, <i>l.</i>	Ditto, <i>l.</i>
	<i>spinosi</i> , Lam. . . . .		Ditto, <i>l.</i>
	<i>Theonea clathrata</i> , Lam. . . . .	Ditto, <i>l.</i>	Ditto, <i>l.</i>
	<i>Idmonia triquetra</i> , Lam. . . . .	Ditto, <i>l.</i>	Ditto, <i>l.</i>
	<i>Alcyon dichotoma</i> , Lam. . . . .	Ditto, <i>l.</i>	Ditto, <i>l.</i>
	<i>Reniera dihyana</i> , Lam. . . . .	Ditto, <i>l.</i>	Ditto, <i>l.</i>
	<i>Smithi</i> , Phil. . . . .	Scarborough, <i>l.</i>	
	<i>Terebellina ramosissima</i> , Lam. . . . .	Bath, <i>l.</i>	Ditto, <i>l.</i>
	<i>anthlope</i> , Lam. . . . .		Ditto, <i>l.</i>
	<i>Thamnostoma Lamourouxii</i> , } <i>Le Sauvage</i> . . . . . }		Ditto, <i>l.</i>
	<i>Millipora straminea</i> , Phil. . . . .	Scarborough, <i>l.</i>	
	<i>dimetosa</i> , Lam. . . . .		Ditto, <i>l.</i>
	<i>corymbosa</i> , Lam. . . . .		Ditto, <i>l.</i>
	<i>compta</i> . . . . .		Ditto, <i>l.</i>
	<i>pyriformis</i> . . . . .		Ditto, <i>l.</i>
	<i>macrochelis</i> . . . . .		Ditto, <i>l.</i>
	<i>Conodictyum striatum</i> . . . . .		Streitberg.
Jamellifera . . . . .	<i>Madrepora limbata</i> . . . . .		Heidenheim.
	<i>Pavonia tuberosa</i> . . . . .	Wiltshire, Yorkshire, <i>m.</i>	
	<i>Explanaria mesenterina</i> , Lam. . . . .		
	<i>lobata</i> . . . . .		Raireuth.
	<i>alveolaris</i> . . . . .		Ditto.
	<i>Agarcia rotata</i> . . . . .		Randenber.
	<i>boletiformis</i> . . . . .		Scissons.
	<i>crassa</i> . . . . .		Randen.
	<i>granulata</i> . . . . .		Hatthelm.
	<i>Moaddopa astrordes</i> . . . . .		Giengen.
	<i>tenella</i> . . . . .		Ditto.
	<i>Soemmeringi</i> . . . . .		Near Basle.
	<i>virgineum</i> . . . . .		Chaumont.
	<i>Astraa microconus</i> . . . . .		Muggendorf.
	<i>concinna</i> . . . . .		Giengen.
	<i>oculata</i> . . . . .		Ditto.
	<i>alveolata</i> . . . . .		Heidenheim.
	<i>helianthoides</i> . . . . .		Ditto, Giengen.
	<i>confusus</i> . . . . .		Ditto, ditto.
	<i>rosacea</i> . . . . .		Basle.
	<i>caryophylloides</i> . . . . .		Giengen.
	<i>cristata</i> . . . . .		Ditto, Heidenheim.
	<i>agrarites</i> . . . . .		Salzburg.
	<i>sexradiata</i> . . . . .		Giengen.
	<i>limbata</i> . . . . .		Ditto.
	<i>formosa</i> . . . . .		Salzburg.
	<i>pentagonalis</i> , <i>m.</i> . . . .		Hatthelm.

Geology. Ch. II.	Family.	Name.	British Localities.	In the Oolites of Württemberg, Bavaria, France, &c.	Geology. Ch. II.
	Lamellifera	<i>Astræa gracilis</i> , m.		Boll.	
		<i>explanata</i> .....		Württemberg.	
		<i>tubulosa</i> .....		Ditto.	
		<i>tubulifera</i> , Phil.	Wiltshire, m. Yorkshire, m.		
		<i>favosoides</i> , Smith.	Wiltshire, m. Oxon, m. Yorkshire, m.		
		<i>inaequalis</i> , Phil.	Malton, m.		
		<i>micrastron</i> , Phil.	Yorkshire, m.		
		<i>arachnoides</i> , Phil.	Malton, Wiltshire, &c. m.		
		several other species, Smith, in the lower oolite.		Ditto.	
		<i>Lithodendron elegans</i> .....		Ditto.	
		<i>compressum</i> .....		Salzburg.	
		<i>granulosum</i> .....			
		<i>Caryophylla annulata</i> , Flem.	Wiltshire, m.		
		<i>cylindrica</i> , Phil.	Malton, &c., Yorkshire, m.	Normandy, l.	
		<i>truncata</i> , Lam.		Ditto.	
		<i>Breissoni</i> , Lam.			
		<i>convexa</i> , Phil.	Whitby coast, l.		
		other species	Wiltshire, Yorkshire, &c. l. and m.	Ditto.	
		<i>Cyathophylum tuffinabulum</i> .....		Banz, Bamberg.	
		<i>mastra</i> .....		Ditto, ditto.	
		<i>Turbinolia dispa</i> , Phil.	Malton, &c. m.	Salzburg.	
		<i>cuneata</i> .....			
		other species	Near Bath, l.		
		<i>Anthophyllum turbanatum</i> .....		Hatthheim, Heidenheim.	
		<i>obconicum</i> .....		Ditto, ditto.	
		<i>sessile</i> .....		Thurnau.	
		<i>Fungia orbiculata</i> , Lam.	Bath, l.	Normandy, l.	
		<i>lævis</i> .....		Switzerland.	
		<i>numismalis</i> .....		Giengen.	
		<i>polymorpha</i> .....		Dauphiné.	
		<i>undulata</i> .....		Salzburg.	
		<i>discoidea</i> .....		Ditto.	

## RADIARIA.

Family.	Name.	Foreign and British Localities in Lias	British Localities in Oolite.	Foreign Localities in Oolite
Crinoidea	<i>Eugeniocrinus caryophyllatus</i> , G.			Baireuth, Württemberg, Switzerland.
	<i>nudus</i> , G.			Streitberg, Muggendorf, Switzerland.
	<i>compressus</i> , G.			Baireuth, Württemberg.
	<i>pyriformis</i> , M.			Randenberg.
	<i>moniliformis</i> , M.			Baireuth, Switzerland.
	<i>Hoferi</i> , M.			Streitberg, ditto.
	<i>Solanocrinus costatus</i> , G.			Giengen, Heidenheim.
	<i>scrobiculatus</i> , M.			Thurnau, Streitberg.
	<i>Jægeri</i> , G.			Baireuth.
	<i>Encrius echnatus</i> , Schl.			Haute Saone.
Pentacrinus	<i>bracteatus</i> .....	Whitby, Lyme, Boll, &c.		
	<i>subangularis</i> .....	Rutland	Oxfordshire, l.	
	<i>basaltiformis</i> .....	Alsace.		
	<i>tuberculatus</i> .....	Ditto.		
	<i>caput Meduse</i> .....	Lyme, Whitby, Alsace.	Yorkshire, l. Wiltshire, l.	Alsace.
	<i>scalaris</i> , G.		Wiltshire, l.	
	<i>cingulatus</i> , M.			Streitberg, Thurnau.
	<i>pentagonalis</i> , G.	Boll		Ditto, ditto.
	<i>moniliformis</i> , M.	Baireuth.		
	<i>subulcatus</i> , M.	Ditto.		
	<i>subferus</i> , M.			Streitberg.
	<i>paradoxus</i> , G.			Baireuth, Württemberg.
	<i>Jurensis</i> , M.			Haute Saone.
	<i>Apocrinus rotundus</i> .....	Bath, l.		Alsace, Württemberg.
	<i>elongatus</i> .....	Ditto, l.		Soleure, Reft.
Rhodocrinus	<i>rosaceus</i> , Schl.			Soleure, Württemberg.
	<i>mespiliformis</i> , G.			Heidenheim, Giengen.
	<i>Mülleri</i> , Schl.			Hatthheim, Württemberg.
	<i>flexuosus</i> , G.			Württemberg.
	<i>obconicus</i> , G.		Ditto.	
	<i>Rhodocrinus ? echnatus</i> , G.		Malton, m.	Amberg, Switzerland.
Stellerida	<i>Comatula pinnata</i> , G.			Solenhofen.
	<i>tencella</i> , G.			Ditto.
	<i>pectinata</i> , G.			Ditto.
	<i>filiformis</i> , G.			Ditto.
	undescribed, Phil.	Frethern, Gloucestershire.		
Ophiura	<i>Mülleri</i> , Phil.	Staithes, Yorkshire.		Ditto.
	<i>speciosa</i> , M.			Ditto.
	<i>carinata</i> , M.			
Asterias	<i>lumbicalis</i> , Schl.	Walzendorf, Lichtenfels.		
	<i>lanceolata</i> , G.	Lichtenfels.		
	<i>arenicola</i> , G.	Porta Westphalia, l.		

Geology. Ch. II.	Family.	Name.	Foreign and British Localities in Lias.	British Localities in Oolite.	Foreign Localities in Oolite.	Geology. Ch. II.
Stellerida	Asterias	Jurensis, M.			Baireuth, m and A.	
		tabulata, G.			Streitberg.	
		seutata, G.			Ditto, Heiligenstadt.	
		stellifera, G.			Streitberg.	
		prisca, G.	Wasseraufingen, Würtemb.			
		other species		Bath, L. Malton, m. Yeovil, L.		
Echinida	Cidaris	maximus, M.			Baireuth.	
		Blumenbachii, M.	Pretzfeld		Thurnau, Muggendorf.	
		nobilis, M.			Baireuth.	
		elegans, M.			Ditto.	
		moniliferus, G.			Switzerland.	
		marginatus, G.			Bavaria, Switzerland.	
		coronatus, G.		Wiltshire, m. Yorkshire, m.	Thurnau, Streitberg.	
		florigemma, Phil.			Streitberg.	
		propinquus, M.			Aldorf, Randen.	
		glandiferus, G.			Dinschugen.	
		Schmideli, M.			Enneberg in Tyrol.	
		Buchii, M.			Swabia, Switzerland.	
		crenularis, G.			Baireuth.	
		subangularis, G.			Streitberg, Ratisbon.	
		variolaris, G.		Somersetshire, L. Yorkshire,		
		vagans, Phil.		L. Yorkshire, m. L.		
		intermedia, Phil.	Spines of Cidaris	Yorkshire, Wilts, m.		
		monilipora, Phil.	Somersetshire and Yorkshire.	Yorkshire, m.		
		other species		Near Bath, L.		
		Echinus gemmans, Phil.		Yorkshire, m. Yorkshire, L.		
		lineatus, G.			Regensburg, Basle.	
		excavatus, Leske.			Regensburg.	
		nodulosus, M.			Baireuth.	
		hieroglyphicus, G.			Regensburg, Thurnau.	
		sulcatus, G.			Near Baireuth, &c.	
		Galerites depressus, Lam.		{ Yorkshire, m. L. Bath L. }	Bavaria, Wurtemberg.	
		speciosus, M.		Haute Saone, m.		
		patella, M.		Oxfordshire, L. Normandy, L.	Heidenheim.	
		Nucleolites granulatus, M.			Amberg, Streitberg.	
		semiglobus, M.			Pappenheim, Manheim.	
		excentricus, G.			Kehlheim.	
		canaliculatus, G.			Staffelberg.	
		scutatus, G.			Switzerland.	
		*testudinarius, G.			Baireuth.	
		columbana, G.			North of France, L.	
		Clypeus sinuatus, Leske		{ Oxfordshire, m. L. Somer-		
		emarginatus, Phil.		setshire, L. Yorkshire, m.		
		dumdiatus, Phil.		Yorkshire, m.		
		clunicularis, Smith		Ditto, m.		
		orbicularis, Phil.		{ Yorkshire, L. Normandy, L.		
		semisulcatus, Phil.		Bath, L. Yorkshire, m.		
		Spatangus ovalis, Phil.		Bath m. &c.		
		intermedius, M.		Yorkshire, L.		
		retusus, Lam.		Ditto, L. m.		
		carinatus		Scarborough, m.		
		capistratus			Blaubeuren, Wurtemberg.	
		Clypeaster pentagonalis, Phil.			Blaubeuren.	
				Malton m.	Baireuth, Wurtemberg.	

## CONCHIFERA. (The names chiefly from Sowerby.)

Family.	Name.	In Lias	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.
Plagymyona	Pholas recondita, Phil.			Malton.	
	compressa			Oxford	Heddington.
	Gastrochlamys tortuosa		Bath, Yorkshire?		
	Panopaea gibbosa		Yorkshire, Dundry.		
	intermedia		Dundry.		
	Pholadomya Murchisoni	In Strasburg Mus.	{ Breta. Normandy,	} Yorkshire.	
			Yorkshire. Savoy		
	hirata	Normandy.	Dundry, Haute Saone.		
	deltoides		Near Bath, Scarborough	Ditto.	
	simplex, Phil.		Near Bath, Scarborough	Cave, Scarborough.	
	obsoleta, Phil.			Scarborough.	
	obliquata, Phil.	Yorksh. Gundershofen	Yorkshire.		
	ovalis		Ditto.	Normandy.	Portland. (Conyb.)
	acaticosta		Ditto.	Angoulême, Cahors.	
	nana, Phil.		Ditto.		
	producta		Ditto, Bath.		
	fidicula		Yorksh. Somers. Savoy.		
	obtusa		Dundry.		

Geology. Ch. II.	Family.	Name	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.	Geology. Ch. II.
	Phagymena	Pholadomya ambigua	{ S of France. Soleure, Bahlingen .....	Dundry .....	Normandy.		
		aequalis .....	Normandy, Soleure.	Normandy .....		Weymouth.	
		gibbosa .....					
		Proteii, Ht. ....				Havre.	
	Mya	v. scripta .....	Yorkshire.	Bedford, Brora, Alsace.			
		literata .....		Bath, Yorkshire	Brora, Yorkshire.		
		angulifera .....		Bath, Alsace?			
		calceiformis, Phil. ....		Yorkshire.	Yorkshire.		
		dilatata, Phil. ....		Ditto.			
		aquata, Phil. ....		Ditto.			
		depressa .....			Yorkshire? Havre	Yorkshire.	
		mandibulata .....				Angoulême.	
	Lutraria	Jurassii, Ht. ....		Ligny.			
	Mastra	.....		Brandshy, Yorkshire.			
	Amphidesma	decurta- tum, Phil. ....		Yorkshire coast, Bath.			
		recurvum, Phil. ....			Yorkshire	Havre.	
		secunformis, Phil. ....		Ditto, ditto.		Ditto.	
		donaciformis, Phil. ....	Whitby coast.				
		rotundatum, Phil. ....	{ Whitby coast, Bath- ingen, Wuldhæu- sethof.				
	Corbula	cardioides, Phil. ....	{ Yorkshire coast, Bath- ingen, Rhun, Meurthe.	Westow in Yorkshire			
		depressa, Phil. ....		Yorkshire.			
		obscura .....		Brora.			
		curtansata, Phil. ....			Ditto.		
	Sanguinolana	undulata .....		Brora, Scarborough, Bath	Scarborough.		
		elegans .....	Yorkshire, Lincolnshire.				
	Corbis	uniformis, Phil. ....	Whitby.				
		levis .....			Yorkshire		
		ovalis, Phil. ....			Ditto.		
	Tellina	amphata, Phil. ....			Ditto.		
	Psammobia	bevigata, Phil. ....		Yorkshire.	Ditto.		
	Lucina	despecta, Phil. ....		Ditto.			
		ciassa, Phil. ....			Ditto.		
		licata, Phil. ....			Ditto		
	Crassina, or Astarte	minima, Phil. ....	Whitby coast.	R. H. Bay, Yorkshire.	Haute Saone.	Haute Saone	
		elegans .....		Yorkshire coast.			
		lurida .....		Gloucestershire.	Scarborough.		
		excavata .....		Dundry.			
		trigonalis .....		Ditto.			
		ovata, Smith .....			Yorkshire, N. Wias		
		orbicularis .....		Aycliff.			
		pumila .....		Ditto.			
		ahena, Phil. ....			Maiton.		
		extensa, Phil. ....			Ditto		
		carinata, Phil. ....			Yorkshire		
		lineata .....			Heddington		
		cuneata .....				Chilmark, near Ayles- bury.	
		placata .....		Normandy			
		rugata .....		Ditto.			
		imbricata .....		Ditto.			
		Voltz. Haen. ....		Vesoud? Banz.			
		vancosa .....		Felmersham.			
	Venus	.....	Yorkshire.	Yorkshire, Bath.	Yorksh. Normandy, &c.		
	Cythera	dolabra, Phil. ....		Ditto	Yorkshire.		
		trigonellaris, Voltz .....		Gundershofen			
		lucinea, Voltz. ....		Ditto			
		cornea, Voltz. ....		Ditto			
	Pullastra	recondita, Phil. ....		Yorkshire.			
		oblata, Phil. ....		Ditto			
		undetermined .....	Whitby.				
	Cardium	truncatum .....	Whitby coast.				
		cognatum, Phil. ....		Ditto.			
		acutangulum, Phil. ....		Ditto.			
		incertum, Phil. ....		Ditto.			
		gibberulum, Phil. ....		Ditto.			
		striatulum, Phil. ....		Ditto.			
		dissimile .....		Collyweston?	Brora	Portland, near Ayles- bury, &c.	
		semiglabrum, Phil. ....		Yorkshire.			
		citrinoides, Phil. ....		Ditto.			
		lobatum, Phil. ....			Yorkshire		
		striatulum .....		Yorkshire, Brora.			
		multicostatum, Beau. ....	Whitby				
	Cardita	similis .....		Dundry, Yorkshire.	Ditto.		

Geology. (Ch. II.)	Division.	Name	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.	Geology. (Ch. II.)
	Plagymyona	Isocardia rostrata	.....	Cotswolds.		{ Portland, Kimmeridge, Haute Saone.	
		excentrica, Volta.	.....				
		concentrica	.....	Yorkshire.			
		nitida, Phil.	.....	Ditto.			
		minima	.....	Ditto, Wilts.			
		striata, Dorbigny	.....			Ditto, ditto, ditto.	
		angulata, Phil.	.....	? Yorkshire.			
		tumida, Phil.	.....		Yorkshire.		
		rhomboidalis, Phil.	.....		Ditto.		
		tenera	.....	Kelloway in Wilts.			
	Hippopodium	ponderosa	{ Whitby coast, South		Ditto.		
		sum	{ of England				
	Trigonia	literata, Y and B.	{ Whitby coast.				
		navis, Lam.	.....	Gundershofen.			
		costata	.....	Bath, Yorksh. Alsace.	Ditto, Oxfordshire		
		striata	Figeac, S of France	Yorkshire, Dundry.			
		elongata	.....	Alsace, Wilts.	Normandy.		
		duplicata	.....	Sodbury, Normandy.			
		angulata	.....	Somersetsh. Yorksh.			
		conjungens, Phil.	.....	Yorkshire.			
		imbricata	.....	Anchiff.			
		cuspidata	.....	Ditto.	Haute Saone.		
		pullus	.....	Ditto.			
		clavellata	.....	Bath, Yorksh. Brora.			
		gibbosa	.....			Portland, Tisbury.	
		incurva, Bennett.	.....			Tisbury.	
	Unio?	crassissimus	Lincolnshire, &c.				
		crassiusculus	Yorkshire.				
		Lasteri	Ditto.	Middle & S of England.			
		concinus	{ Yorkshire, Bath, Gmündt.	Bath.			
		peregrinus, Phil.	.....	Yorkshire, Bath, &c.			
		abductus, Phil.	Yorkshire.	Yorkshire.			
	Modiola	levis	South Wales.				
		depressa	{ Central and Southern				
			{ England.				
		numma	Ditto, ditto.				
		hibana	South Wales, Whitby.				
		scalpium	{ Whitby coast, West of Scotland, &c.				
		plicata	.....	Bath, Collyweston, Charnar.			
		cuneata	.....	Scarborough, Lancashire.			
		gubbiata	.....	Yorkshire, Bath.			
		angulata	.....	Yorkshire coast	Malton		
		aspera	.....	Ditto.			
		reniformis	.....	Bath.			
		gibbosa	.....	Ditto, Charnar.			
		bipartita	.....	Yorkshire, Brora.			
		pulchra, Phil.	.....	Scarborough, Brora.			
		subemarginata, Lam.	.....	Normandy.			
		elegans	.....	Normandy.			
		tulpea, Lam.	.....		North of France.		
		pallda	.....	Brora.			
		flvida, Goldf.	.....	Chaufou.			
		ventricosa, Goldf.	.....	Soleure.			
		inclusa, Phil.	.....	Malton.			
	Lithodomus		.....	Bath, North of France.			
	Mytilus	pectinatus	.....			{ Weymouth, Thame, Rochelle	
		emarginatus, Phil.	.....	Whitby coast.			
		amplus	.....	Bath.			
		sublevis	.....	Felmersham.			
		solenoides	.....			Chesh.	
	Nucula	ovum	Whitby.				
		complanata, Phil.	Ditto.				
		variabilis	.....	Bath, Yorkshire.			
		lachryma	.....	Ditto.			
		axiformis, Phil.	.....	Yorkshire.			
		claviformis	South of France	Northamptonshire.			
		mucronata	.....	Anchiff, near Bath.			
		elliptica, Phil.	.....		Scarborough.		
		nuda, Y. and B.	.....		Ditto.		
		pectinata	.....	Wilts.	Normandy.		
		myoidea	Mende, Bauz				
		Hammeri, Deff.	.....	Gundershofen.			
		acuminata, V. Buch.	.....	Wiesgoldingen.			
		lobata, V. Buch.	.....	Mitzingen, Bopfinger.			

Geology. Ch. II.	Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite	Geology. Ch. II.
	Plagymyona	Nucula subovalis, Goldf.		Wasseraalingen.			
		rostrata		Ditto.			
		elongata		Ditto.			
		arcacea		Banz, Baireuth.			
		Pectunculus minimus		Ancliff.			
		oblongus		Ditto.			
		Arca quadrisulcata			Malton.		
		semula, Phil.			Ditto.		
		pulchra		Ditto. Rochelle.			
		trigonella, Haen.		Wasseraalingen.			
		elongata, Haen.		Ditto.			
		rostrata, Haen.		Ditto.			
		Cucullæa oblonga		Collyweston, Dundry.	Ditto.		
		elongata		Gloucestershire.	Yorkshire.		
		reticulata, Phil.		Yorkshire coast.			
		cancellata, Phil.		Ditto.			
		imperialis, Bean.		Ditto.			
		cylindrica, Phil.		Yorkshire			
		minuta		Ancliff			
		rudis		Ditto.			
		contracta, Phil.			Malton.		
		triangularis, Phil.			Ditto.		
		concinna, Phil.			Scarborough		
		pectinata, Phil.			Malton.		
		decussata		Normandy.			
		Pecten squamosus, V.	Between Nuremberg				
		Buch	and Augsburg.				
		contrarius, V. B.	Wittberg.				
		canaliculatus, G.	Culmbach.				
Mesomyona	Pinna folium, Y. and B.	Whitby coast.					
	granulata, Bl.	Alsace, Aronanche	La Rochelle.				
	quadrivialis, Bl.	Alsace.					
	mitis, Phil.				Scarborough.		
	lanceolata				Scarborough coast.		
	cuneata, Bean.			Near Coxwold, Yorksh.			
	pinnigera			Normandy	Normandy.		
	Trigonellites, or Apty-						
	chus antiqua-				Malton, Yorkshire.		
	tus, Phil.						
	pictus, Phil.				Scarborough.		
	discus				Solenhoten		
	lævis	Banzberg near Amberg.					
	bullatus, V. Meyer	Banz, Boll.					
	elasma, V. Meyer	Ditto, ditto.					
	Gervillia lata, Phil.			Yorkshire coast			
	acuta			Collyweston	Yorkshire.		
	aviculoides			Gundershoten, Boll.			
				Gems, Nurem-			
				berg, Dundry.	Oxford, Yorkshire		
	pernoides, Desl.			Normandy	Normandy.		
	siliqua, Desl.			Ditto	Ditto.		
	monotis, Desl.			Ditto.			
	costellata, Desl.			Ditto			
	Aricula lanceolata	Lyme.					
	elegantissima,				Malton.		
	Phil.						
	tonopluma, Phil.				Ditto		
	ovalis, Phil.				Ditto.		
	expansa, Phil.			Near Malton	Ditto.		
	Braamburghensis.			Scarborough.	Broia, Scarborough.		
	inaequivalvis	Yorkshire coast, Lyme,		Yorkshire coast, Nor-			
		Baireuth, Harz, Gun-		mandy, Banz, Schep-			
		dershofen		penstedt.			
	cygnipes, Phil.	Whitby coast.					
	ovata			Stonesfield.			
	costata			Bath, Normandy.			
	echinata	? Yorkshire.		Bath, Lancashire.			
	Melagrina Cadomen-						
	sis, Deffr.			Caen.			
	Plagiostoma Heimanni		Yorkshire, Bath, Al-				
			sace.				
	giganteum		Bath, Yorkshire, Gun-				
			dershofen, &c.				
	rusticum	Mittau			Yorkshire.		
	semilunare	Alsace.					
	punctatum	South Wales, Figenc.	Normandy, Dundry.				
		Whitby, Pickering,					
	pectinoideum	Vachingen.					
	concentricum	West of Scotland.					
	duplicatum	Rochfeldau, Bath.	Normandy		Ditto.		

Geology. Ch. II.	Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.	Geology. Ch. II.
	Mesomyon.	Plagiostoma leviusculum			Yorkshire, Oxfordshire, South of France.		
		rigidum			Oxfordshire, Yorksh. France.		
		rigidulum, Phil.		Scarborough.			
		cardiiforme		Yorkshire, Gloucestersh.			
		interstinctum, Phil.		Yorkshire.			
		ovale		Bath, Mauriac.	Streitberg.		
		obscurum.			Kelloways.		
		sulcatum	South of France.				
		transversum, V.		Stufenberg, Bopfingen.			
		Buch.					
	Lima	gibbosa		Bath, Normandy.			
		rudis		Yorkshire	Malton, &c. Oxford, Brora.		
		proboscidea		Yorkshire, Dundry, Normandy, Soleure, Baureuth, Basle.		Weymouth, Neuf- chatel	
		antiqua	Middle and South of England, France.				
	Pecten	lamellosus.				Chicks Grove, Thame.	
		sublaevis, Y. & B.	Whitby coast.				
		equivalvis	Yorkshire coast, Avalon.	Bath, Gloucestershire.			
		dentatus	Bollerbad, Leicestersh.				
		virguliferus, Phil.	Germany.	Whitby coast.			
		rigidum		Near Bath.			
		lens		Bath, Haute Saone.	Oxford, Malton		
		obscurus		Stonesfield, Normandy.			
		fibrosus		Bath.			
		laminatus		Ditto, Stonesfield.			
		annulatus		Felmersham.			
		barbatus	Bath, Normandy	Dundry.			
		abjectus, Phil.		Yorkshire	Oxford, Yorkshire.		
		vagus		Bath, Yorkshire	Yorkshire.		
		demissus, Phil.		Yorkshire.	Ditto.		
		similis		Haute Saone	Oxford.		
		viridescens			Ditto, Yorkshire, &c		
		cancellatus, Beaun.			Yorkshire		
		macquostatus, Phil.			Oxford and Yorkshire.		
		corneus		Normandy.			
	Monotis	salina, Beaun.			Regensburg.		
		similis, Mun.			Pappenheim.		
		decussata, Mun.		Hildesheim, Bucke- brag, &c.			
		concinna, G.		Minden, Wurtemberg			
	Ostrea	leviuscula	Bath, Amberg.	Felmersham, Alsace	Yorkshire, Normandy.		
		Marshalli		Bath, Normandy, Alsace			
		pilantia		Bath, Oxon, North of France.			
		acuminata					
		solitaria		Bath, Yorkshire.	Weymouth, Yorkshire, Havre.		
		Meadii		Bath.			
		obscura		Ditto.			
		costata		Ditto, North of France. Buxweiler.			
		sulcifera, Phil.		Western Yorkshire, Wilts, Haute Saone.			
		rugosa		Bath			
		gregaria			Wilts, Oxon, Wey- mouth.		
		angustula, Beaun.			Yorkshire.		
		inequalis			Scarborough		
		undosa, Beaun.			Ditto.		
		archetypum			Ditto.		
		deltoides			Havre, Oxfordshire, Yorkshire.		
		expansa			Chicks Grove, &c.		
		minima, Desl.			Normandy.		
		plicatilis			Ditto. (De Caum.)		
		carinata, Lam.			Ditto.		
		pectinata			North of France. (Bo- blaye.)		
		penaria			Ditto, ditto.		
		fabelloides, Lam.			North of France.		
		tubulifera, Phil.					
		M. S.		Ditto.			
	Ostrea	irregularis. Mun.	Amberg.				
		ungula, Mun.	Banz, Amberg.				



Geology. Ch. II.	Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.	Geology. Ch. II.
	Mesonozona	<i>Ostrea synnema</i> , Mün....	Baireuth.				
		<i>simplicata</i> , Mün. Ditto.					
		<i>rimosa</i> , V. Buch. Bahligen.					
		<i>Exogyra digitata</i> .....			Wilts.		
		<i>mima</i> , Phil. ....			Yorkshire.		
		<i>crassa</i> .....		Bath.			
		<i>reniformis</i> , Goldf. ....		Westphalia.			
		<i>Gryphaa incurva</i> .....	{ Bath, Lincoln, Bayeux, Metz, Scotland.				
		<i>cymbium</i> .....	Figeac, Amberg .....	? Caen.			
		<i>depressa</i> , Phil. ....	Yorkshire.				
		<i>obliquata</i> .....	{ Bath, Scotland, South of France.				
		<i>Maccullochii</i> ...	{ Scotland, Yorkshire, Bath, Normandy.				
		<i>gigantea</i> .....	Gloucestershire .....	Ilminster.			
		<i>gigas</i> , Schl. ....	Mezieres, near Caen.				
		<i>dilatata</i> .....			{ Wilts, Yorkshire, Haute Saone, &c.		
		<i>bullata</i> .....			Lincolnsh. Yorksh. Brora.		
		<i>inhærens</i> , Phil. ....			Yorkshire.		
		<i>nana</i> .....			{ Oxford, Brora, North of France.		
		<i>chamæformis</i> , Ph. ....			Yorkshire, Brora.		
		<i>minuta</i> .....		Bath.			
		<i>cymbina</i> .....			Kelloway Bridge.		
		<i>virgula</i> , Def. ....			{ Havre, Weymouth, Ox- ford, South of France.		
		<i>lituola</i> , Lam. ....		North of France.			
		<i>columba</i> , B? .....		Northamptonshire.			
		<i>Plicatula spinosa</i> .....	{ Yorkshire, Bath, He- brides, Normandy.	{ Gundershofen.			
		<i>squamosa</i> , Goldf. ....		Elligser, Brink.			
		<i>Inoceramus dubius</i> .....	Whitby coast.				
		<i>Posidonia Broannii</i> , Goldf.	Ubstadt, near Bruchsal.				
		<i>Perna quadrata</i> .....		Yorkshire .....	Yorksh. Northamptonsh.		
		<i>isognoides</i> , Goldf. ....		Gundershofen .....	Vaches Noires, Germs.		
		<i>Crenatula ventricosa</i> ...	Yorkshire, Bosworth.				
Brachopoda		<i>Lingula Beani</i> , Phil. ....		Yorkshire, Gundershofen.			
		another species .....	Waldenheim, Bas Rhin.				
		<i>Orbicula reflexa</i> .....	Yorkshire coast.				
		<i>radiata</i> , Phil. ....			Malton.		
		<i>granulata</i> .....		Bath.			
		<i>latissima</i> .....		Yorkshire.			
		<i>Spirifera Walcottii</i> ....	{ Bath, Yorkshire, He- brides, South of France				
		3 other species .....	Bath. (Smith.)				
		<i>verrucosa</i> , V. Buch. ....	Württemberg.				
		<i>granulosa</i> , Goldf. Ditto.					
		<i>Terebratula punctata</i> ...	Rutland, Leicestershire.				
		<i>ornithocephala</i> .....	Lyme, Figeac .....	Near Caen, Jura .....	Yorkshire, Wilts.		
		<i>lampax</i> .....	Lyme.				
		<i>serrata</i> .....	Ditto.				
		<i>acuta</i> .....	Yorkshire.				
		<i>bidens</i> , Phil. ....	{ Ditto, Gloucestershire, Alsace, Württemberg				
		<i>triplicata</i> , Phil. ....	{ Yorkshire, Württem- berg, Thurnau.				
		<i>trilineata</i> , Y. & B. ....	Yorkshire .....	Near Stokesley.			
		<i>cfurgena</i> .....	Bath.				
		<i>tetraëdra</i> .....	{ Rutland, Lincolnshire, Yorkshire.	{ Aynho			
		<i>obovata</i> .....		Bath, Wilts.			
		<i>intermedia</i> .....		{ Bath, Lincolnshire, Yorkshire, Alsace ..	{ Yorkshire.		
		<i>digona</i> .....		Bath, Wilts, Caen.			
		<i>globata</i> .....		Yorkshire, Nunnery ...	? Ditto.		
		<i>perovalis</i> .....		Bath, Grantham.			
		<i>bullata</i> .....		Near Frome.			
		<i>emarginata</i> .....		Ditto.			
		<i>maxillata</i> .....		Near Bath.			
		<i>sphaeroidalis</i> .....		Dundry.			
		<i>cornuta</i> .....		Ilminster.			
		<i>resupinata</i> .....		Ditto.			
		<i>trigmetra</i> .....		Felmersham, Bedfordsh.			
		<i>cearctata</i> .....		Bath.			
		<i>reticulata</i> .....		Frome.			
		<i>hemisphaerica</i> .....		Anciff.			
		<i>rudis</i> .....		Amberg.			
		<i>ovata</i> .....			Ditto.		
		<i>bucculenta</i> .....			Ditto.		

Geology. Ch. II.	Division.	Name.	In Lias.	In Lower Colite.	In Middle Colite.	In Upper Colite.	Geology. Ch. II.
	Brachiopoda.	Terebratula ovoides . . . . .		Yorkshire.	Swiss.		
		spinosa . . . . .		{ Bath, Yorkshire, Charnar, Jura.			
		media . . . . .		Bath, Oxon, Jura.			
		orbicularis . . . . .		Near Bath.			
		fimbria . . . . .		Cheltenham.			
		plicatella . . . . .		Near Bridport.			
		obsoleta . . . . .		Bath, Yorkshire, Jura.			
		concinna . . . . .		Aynhoe.			
		aspera, König . . . . .		Bath.			
		flabellula . . . . .		Ancliff.			
		furcata . . . . .		Ditto.			
		socialis, Phil. . . . .			Yorkshire.		
		inconstans . . . . .				Oxford, Weymouth.	
		impressa, Schl. . . . .			{ Hohenzollern, Stufenberg, Thurnau.		
		nucleata, Schl. . . . .			Ditto.		
		plicata, Lam. . . . .			Streitberg.		
		loricata, Schl. . . . .		Baireuth, Thurnau.			
		spinosa, Schl. . . . .		{ Blomberg, near Donau-eschingen.			
		alata, Lam. . . . .			Hohenzollern, Neresheim.		
		grimas, Herault . . . . .		Caen.			
		trilobata, Mun. . . . .		Porta Westph. Bavaria.			

## MOLLUSCA.

Gasteropoda .	Patella discoides, Schl. . . . .	Gundershofen.
	lævis . . . . .	Whitby.
	rugosa . . . . .	Hampton, Gloucestersh.
	ancyloides . . . . .	Ancliff.
	nana . . . . .	Ditto.
	lata . . . . .	Stonesfield.
	papyracea, Goldf. . . . .	Banz.
	Emarginula tricarinata . . . . .	Ancliff.
	scalaris . . . . .	Ditto.
	Fissurella clathrata . . . . .	Ditto.
	Pileolus plicatus . . . . .	Ditto.
	lævis . . . . .	Ditto.
	Bulla elongata, Phil. . . . .	Scarborough.
	Actæon retusus, Phil. . . . .	Ditto.
	glaber, Phil. . . . .	Yorkshire coast.
	humeralis, Phil. . . . .	Ditto.
	cuspidatus . . . . .	Ancliff.
	acutus . . . . .	Ditto.
	Auricula Sedgwicki, Phil. . . . .	Blue Wick, Yorkshire.
	Cirtus carinatus . . . . .	Cheltenham.
	Leachii . . . . .	Dundry.
	nodosus . . . . .	Ditto, Yeovil.
	cingulatus, Phil. . . . .	Ditto.
	depressus, Phil. . . . .	Ditto.
	Solarium calix, Hyatt . . . . .	Yorkshire.
	conodeum . . . . .	Portland, I.
	Delphinula coronata . . . . .	Ancliff.
	other species . . . . .	Yorkshire.
	Trochus and Plenrotomaria duplicatus } Alsace.	
	similis . . . . .	South of England . . . . . Dundry.
	amblicatus . . . . .	{ Cheltenham, South of France, Soleure . . . . . Normandy.
	anglicus . . . . .	{ Bath, Yorkshire, Thonville, Banz . . . . . Haute Saone, Sherborn.
	ornatus . . . . .	North of France . . . . . Dundry, Normandy.
	granulatus . . . . .	Yorkshire . . . . . Ditto.
	pyramidalis, Bean . . . . .	Blue Wick, Yorkshire.
	bilobatus, Phil. . . . .	Ditto.
	moniliformis, Phil. . . . .	Ditto.
	concavus . . . . .	{ Little Sodbury, Normandy.
	duplicatus . . . . .	{ Little Sodbury, Gundershofen, Banz . . . . .
	dimidiatus . . . . .	Little Sodbury.
	punctatus . . . . .	Dundry, Normandy.
	elongatus . . . . .	{ Dundry, Wiltshire, Normandy.
	abbreviatus . . . . .	Dundry, Normandy.
	fasciatus . . . . .	Ditto, ditto.
	sulcatus . . . . .	Ditto, ditto.
	bicarinatus . . . . .	Ditto, ditto.
	tornatilis, Phil. . . . .	Ditto.

Geology  
Ch. II.

Division.

Name.

In Lias.

In Lower Oolite.

In Middle Oolite.

In Upper Oolite.

Geology  
Ch. II.

Geology Ch. II.	Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.	Geology Ch. II.
	Gastropoda	Trochus & Pleurotoma- ria guttatus, Phil.			Yorkshire.		
		Gibbsii			Normandy.		
		niloticiiformis, Stahl.		Stufenberg.			
		reticulatus		Normandy.	Weymouth, Oxon.		
		decorata, V. Buch.		Neuhausen.			
		rugatus, Benett.				Tisbury.	
		Turbo uncarinatus, Bean		Blue Wick, Yorkshire.			
		laevigatus, Phil.		Ditto.			
		obtusius		Ancliff.			
		undulatus, Phil.	Yorkshire coast.				
		ornatus		Dundry, Gundershofen.			
		sulcostomus, Phil.			Hacknes, Yorkshire.		
		funiculatus, Phil.			Malton.		
		muricatus			{ Scarborough, Wilt- shire, Weymouth.		
		rotundatus		Normandy.			
		costarius, D.			France.		
		trochiformis, Schl. Boll.					
		Phasianella cincta, Phil.		Scarborough			
		angulosa		Porta Westphalica, Haen.			
		Rissoia laevis		Ancliff.			
		acuta		Ditto.			
		obliquata		Ditto.			
		duplicata		Ditto.			
		Turritella quadrivittata, Phil.		Blue Wick, Yorkshire.			
		muricata		Blue Wick	Oxford, &c.		
		excavata				Chilmark, &c.	
		echinata, V. Buch.		Banz, Langheim.			
		Nerinea cingenda		{ Yorkshire, Lincoln- shire, Bath	Yorkshire		
		tuberculata, Blam.	Near Auxerre.		Auxerre.		
		mosae, Des			St. Mihiel, Pouilly.		
		Cerithium ? interme- dium, Haen		Near Minden.			
		Terebra melanoides, Phil.			Malton and Pickering.		
		granulata, Phil.		Scarborough coast	Yorkshire.		
		vetusta, Phil.		Ditto.			
		Natica tumidula		Dundry, Yorkshire.			
		adducta		Blue Wick, Yorkshire.			
		— Smith.		Lincolnshire, Bath, &c.			
		arguta, Smith			Yorkshire, Wilts, &c.		
		nodulata, Phil.			Malton.		
		cincta, Phil.			Ditto.		
		Melania ? Heddingto- nensis		{ Yorkshire, Dundry, Caen, Haute Saone.	{ Yorkshire, Oxon, Weymouth, Kil- heim.	Havre, North Wiltshire	
		striata	? Lymington	Yorkshire.	{ Yorkshire, Oxon, Weymouth.	Havre.	
		vittata, Phil.			Yorkshire.		
		lineata		{ Yorkshire, Dundry, Normandy.			
		Planorbis ? eumphidus ?		? Bath.			
		Ampullaria gigas, Von Stromb.				Kahleberg near Echte.	
		Helicina polita	Cropledy.				
		compressa	Leicestershire.				
		expansa	Lyme.				
		solaroides	Ditto.				
		Nerita sinuosa				Portland	
		laevigata		Dundry.			
		minuta		Ancliff.			
		costata		Dundry, Yorkshire.			
		Rostellaria composita		{ Scarborough, Brora, Wiltshire.			
		hispanosa, Phil.			Scarborough.		
		trifida, Bean			Ditto.		
		— Phil.	Whitby coast.				
		Buccinum unilineatum		Ancliff.			
		Pteroceras ocean, Bl.		Alsace, Mantua.		Havre, Haute Saone	
		Ponti, Bl.				Havre.	
		Pelagi, Bl.				Ditto.	
		Murex Haccanensis, Phil.				Hackness, Yorkshire.	
		Dentalium giganteum, Phil.	Staithes, &c., Yorkshire.				
		cylindricum	Devonshire.				
		quadratum, Phil.		Scarborough.			
	Cephalopoda.	Belemnites tubularis, Y. and B.	Whitby coast.				

Geology. Ch. II.	Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.
	Cephalopoda	<i>Belemnites elongatus</i> , Mill.	Lyme, Whitby.			
		<i>aduncatus</i> , Mill.	Lyme, Bath.			
		<i>compressus</i> , Phil.	Whitby coast.			
		<i>longissimus</i> , Mill.	Lyme, Bath.			
		<i>pistilliformis</i> , Bl.	Charmouth.			
		<i>acutus</i> , Bl.	Ditto.			
		<i>penicillatus</i> , . . . . .	Ditto.			
		<i>brevis</i> , Blain . . . . .	Alais.			
		<i>apicicurvatus</i> , Bl.	Ditto.			
		<i>giganteus</i> , Bl.	Amberg.			
		<i>penicillatus</i> , Bl.	Salins, Anduze.			
		<i>bisulcatus</i> , Bl.	Caen.			
		<i>aalensis</i> , Bl. Voltz.		Bopfingen, Baireuth.		
		<i>conicus</i> , . . . . .	Whitby.			
		<i>sulcatus</i> , Mill.	South of France.	Dundry . . . . .	Malton	
		<i>elipticus</i> , Mill.		Dundry, Haute Saone.		
		<i>abbreviatus</i> , Mill.		Dundry, Yorkshire . . . .	Weymouth	
		<i>fusiformis</i> . . . . .		Stonesfield . . . . .	Malton.	
		<i>gracilis</i> , Phil.			Scarborough.	
		<i>trisulcatus</i> , Bl.		North of France.		
		<i>compressus</i> , Bl.		{ Yorkshire coast, Gundershofen, &c.		
		<i>dilatatus</i> , Bl.	Baireuth . . . . .	{ North of France. (Bohlage.)		
		<i>canaliculatus</i> , Schl.		Haute Saone . . . . .	Haute Saone	
		<i>longus</i> , Voltz.		Ditto.		
		<i>ferruginosus</i> , Voltz.		Swabia, Bavaria . . . . .	Ditto.	
		<i>semisulcatus</i> , Mun.			{ Bohringen, Mögglingen Bahningen	
		<i>sublavatus</i> , Voltz.		Gundershofen		
		<i>subdepressus</i> , Voltz.	Gundershofen.			
		<i>subaduncatus</i> , Voltz.		Ditto.		
		<i>brevifrons</i> , Voltz.		Ditto.		
		<i>ventroplanus</i> , Voltz.	Befort, Gundershofen.			
		<i>longisulcatus</i> , Voltz.		Ditto.		
		<i>tridus</i> , Voltz.		Ditto		
		<i>compressatus</i> , Voltz.	Bahlingen.			
		<i>tenuis</i> , Mun.	Altdorf.			
		<i>paxillosus</i> , Schl.	Befort, Boll			
		<i>acutus</i> , Schl.	Banz, Altdorf			
		<i>crassus</i> , Voltz.	Besancon.			
		<i>tripartitus</i> , Schl.	Altdorf.			
		<i>venustus</i> , Mun.				
		<i>oxyconus</i> , Hehl.	Ditto, Banz, Boll.			
		<i>elongatus</i> , . . . . .	Lyme Regis.			
		<i>curvatus</i> , Hehl.	Banz, Boll.			
		<i>pyramidalis</i> , Mun.	Banz . . . . .		Stutenberg	
		<i>rotundus</i> , Hehl.	Ditto.			
		<i>clavatus</i> , Blain . . . .	{ Lyme, Boll, Amberg, Banz.			
		<i>teres</i> , Stahl.	Gosbach, Wurtemberg.			
		<i>hervigatus</i> , Zieten . .	Boll.			
		<i>papillatus</i> , Phoenig	Ditto.			
		<i>carinatus</i> , Hehl.	Ditto			
		<i>pygmaeus</i> , Zieten . . .	Ditto.			
		<i>unisulcatus</i> , Hart.	Wurtemberg.			
		<i>bisulcatus</i> , Hart . . .	Boll			
		<i>quadrisulcatus</i> , Hart.	Göppingen.			
		<i>tricanaliculatus</i> , . .	{ Hart . . . . .	Stufenberg.		
		<i>quadricanaliculatus</i> , Hart . . .		Ditto		
		<i>quinquecanaliculatus</i> , Hart . . .		Göppingen.		
		<i>pusillus</i> , Mun . . . . .			Strothberg.	
		<i>etiformis</i> , Mun . . . . .			South of Germany.	
		<i>umbilicatus</i> , Bl.		Normandy.		
		<i>gladius</i> , Bl.		Metzingen, Baireuth.		
		<i>Blainvillu</i> , Voltz . . .	Swabia.			
		<i>hastatus</i> , Bl.		Baireuth, Banz, Metz.		
		<i>semihastatus</i> , Bl.		Baireuth.		
		<i>quinquesulcatus</i> , Bl.		Wurtemberg.		
		<i>grandis</i> , Schüller . . .		Stufenberg.		
		<i>tumidus</i> , Zieten . . .		Ditto.		
		<i>acuminatus</i> , Schül.		Ditto.		
		<i>subhastatus</i> , Zieten . .		Ditto.		
		<i>bipartitus</i> , Hart . . .		Grübingen.		
		<i>unicanaliculatus</i> , . .		Donzdorf.		
		<i>bicanaliculatus</i> , . .				
		<i>Hart</i> , . . . . .		Gunzsteden.		

Geology. Ch. II.	Division.	Name.	In Lias.	In Lower Oolite.	In Middle Oolite.	In Upper Oolite.	Geology, Ch. II.
	Cephalopoda.	<i>Nautilus annularis</i> , Phil.	Whitby.				
		<i>truncatus</i> .....	Keynsham.				
		<i>intermedius</i> .....	{ Ditto, Lyme, Württemberg, Alsace.				
		<i>striatus</i> .....	Lyme.				
		<i>astacoides</i> , Y. and B.	Whitby.				
		<i>lineatus</i> .....	Yorkshire, Bath	Yorkshire, Bath, Dundry.			
		<i>obesus</i> .....		Gloucestersh. Normandy.			
		<i>sinuatus</i> .....		Yeovil.			
		<i>excavatus</i> .....		Dorsetshire.			
		<i>hexagonus</i> .....			Yorkshire, Oxon.		
		<i>angulosus</i> , D'Orb.				Isle d'Aix.	
		<i>polygonalis</i> .....		Ditto.			
		<i>reticulatus</i> .....	France.				

## Ammonites.

Group.	Name.	In Lias	British Localities.	In Oolite.	Foreign Localities.	In Oolite.
Arietes, viz	<i>Bucklandi</i> .....	Bath, Whitby			{ Near Donaueschingen, Phil.	
	<i>Conybeari</i> .....	Ditto, ditto			{ Meurthe, near Donaueschingen, Phil.	
	<i>Turneri</i> .....	Whitby, Watchet				
	<i>Brookii</i> .....	Lyme.				
	<i>Smithii</i> .....	Near Yeovil.				
	<i>rotiformis</i> .....	Near Bath.				
	<i>Kridlion</i> , Rein. ....				Stuttgart.	
	<i>obtusius</i> .....	Yorkshire.				
	<i>stellaris</i> .....	Lyme.				
	<i>multicostatus</i> .....	Bath.				
	<i>Walcottii</i> .....	Whitby, Bath, Lyme.			{ North and South of France, Boll, Befort, Achelberg.	
	<i>redarensis</i> .....	Redcar, Yorkshire.				
	<i>Falciferi</i> , &c. ....	<i>Strangwaysii</i> .....		Yeovil, & Gloucestersh. &	{ Gundershofen, Altdorf. } Haute Saone, &	
		<i>elegans</i> .....	Yorkshire	Yeovil, & Bath, &	{ Boll, Normandy.	
		<i>striatulus</i> .....	Whitby		{ Bas Rhin	
Amalthei		<i>Mulgravius</i> , Y. & B.	Yorkshire		{ Boll.	
		<i>Lythensis</i> , Y. and B.	Ditto		{ Meurthe.	
		<i>ovatus</i> , Y. and B.	Ditto.			
		<i>impendens</i> , Y. and B.	Ditto.			
		<i>exaratus</i> , Y. and B.	Ditto.			
		<i>planorbiformis</i> , Mün.			Bavaria	
		<i>canaliculatus</i> , Mün.			{ Woschhaus, m Fürstenberg, m Bahlungen, m.	
		<i>Murchisoni</i> .....		Bridport, Hebrides	{ Gundershofen, Wisgoldingen, Goslar.	
		<i>subradiatus</i> .....	Bath			
		<i>laeviusculus</i> .....	Whitby coast	Dundry		
		<i>depressus</i> , Bon.		Ditto, Bayeux.		
		<i>fenticola</i> , Murch.			{ Thurnau, Bamberg, Dives, Besançon Haute Saone, m.	
		<i>Deluci</i> , Bgt. ....			Neuhausen, m.	
		<i>binus</i> , Sow. ....				
		<i>comensis</i> , V. Buch.			Ditto, m.	
		<i>falcifer</i> .....		{ Dundry, Ilminster, Württemberg	{ Normandy. South of France, Würtemb.	
		<i>sclaris</i> , Phil.		Scarborough calc grit.		
		<i>obliquatus</i> , Y. and B.	Whitby.			
		<i>Boulbensis</i> , Y. & B.	Ditto.			
		<i>jugosus</i> .....		Ilminster, &		
		<i>Greenovii</i> .....	Lyme.		Dunkesbühl, &	
		<i>Loscombi</i> .....	Ditto			
		<i>Stokesi</i> .....		Bridport	{ Normandy. South of France, Württemberg.	
		<i>vittatus</i> , Phil.	Whitby.			
		<i>acutus</i> .....			Normandy	{ Haute Saone, Wasserralingen.
		<i>sigmifer</i> , Phil. ....	Ditto.		Wasserralingen.	
		<i>costulatus</i> , Rein.			{ Waichingen, Dünkeshühl.	
		<i>colubratus</i> , Montf.				
		<i>Johnstonii</i> .....	Watchet.			
		<i>Clevelandicus</i> .....	Whitby coast.			
		<i>crenularis</i> , Phil.	Whitby.			
		<i>heterophyllus</i> .....	Whitby coast.			
		<i>lenticularis</i> , Phil.	Lyme Regis.			
		<i>Hawkerensis</i> , Y. and B.	{ Whitby coast		Württemberg.	
		<i>modulosus</i> , Schl.				

Geology. Ch. II.	Group.	Name.	British Localities.		Foreign Localities.		Geology. Ch. II.
			In Lias.	In Oolite.	In Lias.	In Oolite.	
Amalthei	.....	alternans, V. Buch.				From Bamberg to Switzerland, m.	
		vertebralis		{ Yorkshire, Oxon, m. So-		Haute Saone, m.	
		quadratus		mersetshire, l.		Normandy, l.	
		excavatus		Oxford, m. Walton, m.		{ Normandy, m. Aarau, l.	
						Aldorf, l.	
		Lamberti		Portland, u.		Rochelle, u. Aarau, m.	
		omphaloides		Ditto, u. Hebrides, m.		Bamberg, m. Ellig- serbrink, m.	
		cristatus		Weymouth, u.		Normandy, m.	
		pustulatus, Rein.				Haute Saone, m. Got- tenberg, m. Streit- berg, m.	
		funiferus, Phil.		Yorkshire, m.		Thuridau, m. Coburg, m.	
		discus	Lyme	Bedford, l.		Spaichingen, l.	
		nodosus		Scarborough.			
		flexicostatus, Phil.		Ditto, m.			
	Capricorni	planicostatus	Marston, Lyme		Harz, Amberg, Aldorf.		
		maculatus	Whitby coast.		Bahlingen, Heligoland.		
Planulati		angulatus, Schl.			{ Neckar, Thailfingen,		
		anguliferus, Phil.	Ditto		Willersau, near Schip- penstadt.		
		N.S.			Gundershofen.		
		scutatus, V. Buch			Banz, Goppingen.		
		matrix, Schl.			{ Bahlingen, Brunsrode,		
					Aldorf.		
		finobriatus	Whitby		{ Normandy, Mende,		
					Conflans, Kemmerstorf,		
					Anstorf, Boll, Bahlin- gen, Banz, &c.		
		balteatus, Phil.	Ditto.				
		Jacksoni		Yorkshire, Hebrides.			
		brevispina		Whitby, Hebrides.			
		gagatus, Y. and B.	Whitby coast.				
		annulatus	Whitby &c.		{ Solenne, Lyons, Mont d'Or, Wurtemberg.		
		communis	Ditto				
		angulatus	Ditto				
		crassus, Y. and B.	Whitby, Himalayan mtn				
		biplex	{ Ross, Cromarty, Lin- colnshire			{ Randen, m. Rathshau- sen, m. Strötberg m. Haute Saone, m. Normandy, l. The Swiss Jura, l. Was- seralfingen, l. Wiegol- dingen, Bopfinger	
		Parkinsoni	Bath	Yewell, l.			
		funicularis, V. Buch	Vic				
		triphacatus		Malton, m. Portland, u		{ Randen, m. Swabia. m., Normandy, l.	
		phectilis		Malton, m. Oxford, m.		Haute Saone, Percy le grand Champel, Randen, m.	
		polyphacatus, Rem.				German Jura, m. ?	
		polygyratus, Rem.				Danzdorf, Randen, m.	
		comptus, Rem.				Danzdorf, Amberg.	
		giganteus		Portland, u.		{ Isle d'Aix, u. Syn- birsk, on the Volga.	
		trifidus		Oxford, m.			
		bifurcatus, Schl.				{ Rathshausen, m. Lochenberg, m. Coburg, m. Baa- teuth, m.	
		trifurcatus, Rem.				Wurtemberg	
		phicomphalus		{ Yorkshire, u. Lincoln- shire, u.		Normandy	
		mutabilis				Willibaldsburg near Eichstedt	
		multiradiatus, Reng.				Hohenzollern l. Cam- melhausen, l.	
		Königii	Lyme	{ Wiltshire, m. York- shire, m.			
		Browni		Dundry, l.			
		longidorsalis, V. Buch				Crozeville m. Cava.	
		mutabilis, Phil.		Scarborough, m.			
		planorbis		Watchet.			
		nitescens, Y. and B.	Whitby.				
		arcigerens, Phil.	Ditto, Cheltenham.				
		erugatus, Bean.	Whitby Cave, &c.		Coregna, De la Beche.*		

\* From the same locality Mr. De la Beche figures A. cylindricus, stella, Phillipsii, biformis, Listeri ? coregneusis, Gaudoni, articulatus, discretus, venticonus, comptus, catenatus, trapezoidalis. *Man. of Geol.* p. 319.

Geology. Ch. II.	Group.	Name.	British Localities.	In Lias.	In Polite.	In Lias.	Foreign Localities.	In Oolite.	Geology. Ch. II.
	Dorsati.....	arnatus .....	Whitby, Bath .....						
		Davies .....	Lyme .....				Pouilly near Autun.		
		fibulatus .....	Whitby.						
		subarmatus .....	Ditto.						
		Broderici .....	Portland, u.						
	Coronarii.....	crenatus, Rein. ....							
		Humphrestandus .....	Dundry, l.				South of France.		
		Hollensis, Zieten. ....					Holl.		
		Bechu .....	Lyme.				Rottweil, Bahlingen.		
		Blagdeni .....	{ Scarborough, l. Sher- borne, l., Dundry, l. }						
		Brakenridgii .....	Dundry, l.						
		Vernoni, Bean .....	Scarborough, m. Brora, m.						
		contractus .....	Dundry, l.						
		dubius, Schl. ....							
		Gowerianus .....	{ Scarborough, m. Cro- arty, m. }						
		Buchi .....	Ditto						
	Macrocephali.....	tumidus, Rein. ....							
		inflatus, Rein. ... }							
		Sutherlandia, Sow }	Brora, m., Scarborough, m.						
		sublevis .....	{ Wiltshire, m., York- shire, m. }						
		modiolaris, Smith. ....	Bath, l.						
		Herveyi .....	{ Wiltshire, l., Lincoln- shire, l., Yorkshire, l. }						
		terebatus, Phil. ....	Yorkshire, l.						
		Banksii .....	Sherborne, l.						
		Brochii .....	Dundry, l.						
		Gervillii .....							
		Brongniarti .....	Yeovil, l.						
		subearnatus, Y. & B. Whitby.							
	Armati.....	pearnatus .....	Yorkshire, l., Oxford, l.						
		longispinus.							
		catena .....	Berkshire, m.						
		biarmatus, V. Zieten.							
		athleta, Phil. ....	Yorkshire, m.						
		Ziplus, Hohl.							
		Williamsoni, Phil. ....	Ditto, m.						
		Bakeri .....							
		bifrons, Phil. ....	Scarborough, m.						
		laevigatus .....	Lyme Regis.						
		Birchi .....	Lyme						
	Dentati.....	Jason, Rein. .... }							
		Calloviensis, Sow. }							
		Gulielmi, Sow. ....	{ Wiltshire, m., York- shire, m. }						
		hylas, Rein. ....							
		Dugesi .....	{ Scarborough, m. St. Neot's, m. }						
	Ornati.....	A. Pollux, Rein. ....							
		gemmatus, Phil. ....	Scarborough, m.						
		spinosus, Sow. ....	Weymouth, m.						
		castor, Rein. ....							
		pustulatus, Rein. ....							
	Flexuosi.....	flexuosus, Mün. ....							
		asper .....							
		oculatus, Phil. ....	Yorkshire, m.						

## Unarranged Foreign Species.

A. granulatus, Bt. ....	Coburg, m.
Reineckii, Hohl. ....	Ditto.
gigas, Zieten.	
Sowerbi, Moll. ....	Dundry, l.
Deslongchampsii, } Bobl. .... }	North of France, l.
vulgaris, Bobl. ....	Ditto.
corrugatus, S. ....	Dundry.

Geology. Ch. II.	Family.	Name.	British Localities.		Foreign Localities.		Geology. Ch. II.
			In Lias.	In Oolites.	In Lias.	In Oolites.	
Cephalopoda	A.	<i>interruptus</i> , Schl.	.....	.....	.....	Haute Saone, m.	
		<i>decoratus</i> , Ziet.	.....	.....	.....	Gurtenberg, l.	
		<i>hipartitus</i> , Ziet.	.....	.....	.....	Ditto.	
		<i>bispinosus</i> , Ziet.	.....	.....	.....	Wasseraufingen, l.	
		<i>Scaphites refractus</i> , Rem.	.....	.....	.....	Gammelshausen, l.	
		<i>Yoannii</i> .....	.....	.....	.....	Basses Alpes.	
		<i>Hamites annulatus</i> , Desh.	.....	.....	.....	France.	
		..... Mun.	.....	.....	.....	Rabenstein, Thurnau.	
		<i>Turrites Babili</i> , Ht.	.....	.....	.....	North of France.	
		<i>Onychoteuthis angus-</i>	.....	.....	.....	Solenhofen.	
		<i>ta</i> , Müf. ....	.....	.....	.....	Ditto.	
		<i>Loligo priscus</i> , Rüppell.	.....	.....	.....	Ditto.	
		<i>antiqua</i> , Mun.	.....	.....	.....	Ditto.	
		<i>Sepia hastiformis</i> , Rüpp.	.....	.....	.....	Ditto.	
		.....	.....	Lyme Regis.	.....		
		<i>Rhyncholites</i> .	.....	Lyme, Bath.	.....		

## ANNULOSA.

Name	Lias.	Lower Oolite.	Middle Oolite.
<i>Vermicularia concinna</i> , Phil.	.....	Yorkshire coast.	.....
<i>compressa</i> , Y. and B. }	.....	.....	Scarborough.
<i>ovata</i> .....	.....	.....	.....
<i>nodus</i> .....	.....	Westow, Yorkshire.	.....
<i>Serpula capitata</i> , Phil.	R. Hood's Bay, Yorksh.	.....	.....
<i>depressa</i> , Bean.	.....	Yorkshire coast.	.....
<i>squamosa</i> , Phil.	.....	.....	Ditto.
<i>intestinalis</i> .....	.....	.....	Ditto.
<i>quadrata</i> .....	.....	Scarborough, Bath.	.....
<i>lanceata</i> , Phil.	.....	.....	Ditto.
<i>triangulara</i> .....	.....	Bradford, Wilts.	.....
<i>tetragona</i> .....	.....	Ditto, ditto.	.....
<i>reticulata</i> .....	.....	.....	Shotover, Oxon.

N. B. Goldfuss (*Petrifactionkunde*) has figured and described forty-two species of *Serpula* from the oolitic system of Germany and France. According to Von Dechen their Geological relations are as under:—

From the Lias.		Serpula filaria, G. .... Graefenberg	
<i>Serpula triseriata</i> , Goldf. .... Banz.	.....	<i>socialis</i> , G. .... Bavaria, Swabia.	.....
<i>quinqueresiata</i> , Mun. .... Ditto.	.....	From the Upper Oolites.	
<i>circulata</i> , Mun. .... Ditto.	.....	<i>grandis</i> .....	Heidenheim, (also in lower oolites.)
<i>quinguesulcata</i> , Mun. .... Baereuth.	.....	<i>conformis</i> , G. .... Buxweiler.	.....
<i>complanata</i> .....	Ditto.	<i>delphinula</i> , G. .... Streitberg, Thurnau.	.....
From the Lower Oolites.		<i>gibbosa</i> , G. .... Muggendorf.	.....
<i>limax</i> , G. .... Baereuth.	.....	<i>nodulosa</i> , G. .... Streitberg.	.....
<i>lituiformis</i> , Mun. .... Ditto.	.....	<i>quingueangularis</i> , G. .... Normandy.	.....
<i>capitata</i> , G. .... Streitberg.	.....	<i>prolifera</i> , G. .... Streitberg.	.....
<i>limata</i> , Mun. .... Ditto.	.....	<i>planorbiformis</i> , M. .... Ditto, Thurnau.	.....
<i>pleatilis</i> , Mun. .... Graefenberg.	.....	<i>trochleata</i> , M. .... Streitberg.	.....
<i>spirochutes</i> , Mun. .... Streitberg.	.....	<i>macrocephala</i> , M. .... Thurnau.	.....
<i>tricarinata</i> , G. .... Rabenstein.	.....	<i>heliceiformis</i> , G. .... Neufchatel, Haute Rive.	.....
<i>pentagona</i> , G. .... Streitberg.	.....	<i>quadrata</i> , G. .... Amberg.	.....
<i>quadrilata</i> , G. .... Rabenstein.	.....	<i>convoluta</i> , M. .... Streitberg, Baereuth, &c.	.....
<i>quadrilobata</i> , G. .... Berrach. (Burgundy.)	.....	<i>Deshayesi</i> , M. .... Streitberg.	.....
<i>canaliculata</i> , Mun. .... Streitberg.	.....	<i>spiralis</i> , M. .... Muggend. Nutth. Heidenh.	.....
<i>volubilis</i> , Mun. .... Rabenstein.	.....	<i>flagellum</i> , M. .... Streitberg.	.....
<i>cingulata</i> , Mun. .... Streitberg.	.....	<i>gordani</i> , Schl. .... Nutth. Heidenh. Buxweiler.	.....
<i>substriata</i> , Mun. .... Rabenstein.	.....	<i>intercepta</i> , G. .... Streitberg, Culmbach.	.....
<i>flaccida</i> , G. .... Rabenstein, Alsace.	.....	<i>hum</i> , G. .... Streitberg, Thurnau.	.....

## CRUSTACEA.

Name	Lias.	Lower Oolite	Middle Oolite.
<i>Astacus longimanus</i> Koenig. . Lyme	.....	.....	.....
<i>rostratus</i> , Phil.	.....	Scarborough.	Scarborough, Malton
<i>nitus</i> , Phil. MS	.....	Ditto.	.....
<i>scabrosus</i> , Phil. MS.	.....	.....	Malton.
New genus ? Phil. MS.	.....	.....	Scarborough.
<i>Cancer</i> .....	.....	.....	Malton.

The following are from Solenhofen:—

*Astacus spinimanus*, Germ.  
*leptodactylus*, Germ.  
*modestiformis*, Holl.  
*minutus*, Holl.  
*fuelformis*, Holl.  
*Pagurus mysticus*, Germ.  
*Scyllarus dubius*, Holl.  
*Eryon Cuvieri*, Desm.

*Eryon Schlotzhimii*, Holl.  
*acutus*, Germ.  
*muticus*, Germ.  
*spinimanus*, Germ.  
*Merochyrus locusta*.  
*Palaeon spinipes*, Dem.  
*squillarius*, Dem.  
*Walchii*, Holl.

## INSECTS.

Traces of Insects occur at Stonesfield, and very fine specimens of libellulidæ and hymenoptera at Solenhofen.



This list is principally taken from Von Meyer's *Palæologica* and De la Beche's *Manual*.

*Family of Saurians.*

<i>Pterodauctylus macronyx</i> , Buckl. ....	In lias, Lyme Regis.
<i>longirostris</i> , Cuv. ....	In slaty limestone, Eichstadt.
<i>brevirostris</i> , Cuv. ....	Ditto, ditto.
<i>grandis</i> , Cuv. ....	Ditto, Solenhofen.
<i>Bucklandi</i> , Von Meyer ....	Lower oolite, Stonesfield.
<i>crassirostris</i> , Goldf. ....	In slaty limestone, Solenhofen.
<i>medius</i> , Mun. ....	In oolite, Mannheim.
<i>Munsteri</i> , Goldf. ....	Ditto.
<i>Crocodylus cylindrirostris</i> , Cuv. ....	In lias, Altdorf.
<i>priscus</i> , Soem. ....	In oolite, Mannheim.
<i>Altdorfensis</i> , Cuv. ....	In lias, Altdorf; in Kimmeridge clay, Honfleur, Havre.
<i>Geoffroyi</i> , Von Meyer ....	In Kimmeridge clay, Honfleur, Havre.
<i>Of Mans</i> , Cuv. ....	In oolite ?
undetermined species ....	{ In lias of Yorkshire, Lyme Regis; in cornbrash, Northamptonshire, Stonesfield slate, and coralline oolite of Yorkshire.
<i>Teleosaurus Cadomensis</i> , G. St. H. ....	In oolite, Caen.
<i>Geosaurus Bollensis</i> , Jæg. ....	In lias, Boll.
<i>Soëmmerringii</i> ....	In slaty limestone, Solenhofen.
<i>Megalosaurus Bucklandi</i> ....	In Stonesfield slate.
.....	In oolite, Normandy.
<i>Lacerta Neptunia</i> , Goldf. ....	Mannheim
<i>Iguanodon Mantelli</i> , Von Meyer. ....	In the Wealden formation, Tilgate.
<i>Hydrosaurus</i> ———, Mantell ....	Ditto, ditto.
<i>Pleurosaurus</i> , Goldf., Von Meyer. ....	In slaty limestone, Solenhofen.
<i>Rhacheosaurus gracilis</i> , Von Meyer ....	Ditto, ditto.

*Family Enalosauri*, Conyb.

<i>Ichthyosaurus communis</i> , De la B. and C. ..	In lias, Lyme, Yorkshire, Boll, &c.
<i>tenuirostris</i> , De la B. and C. ....	Ditto, ditto.
<i>platyodon</i> , De la B. and C. ....	Ditto, Lyme, Boll.
<i>intermedius</i> , De la B. and C. ....	Ditto, ditto.
<i>grandipes</i> , Sharpe ....	In lias
<i>conformis</i> , Haslan ....	Ditto, Bath.
other species ....	In the lias and Kimmeridge clay.
<i>Plesiosaurus dolichodermus</i> , Conyb. ....	In lias, Dorsetshire, &c.
<i>recentior</i> , Conyb. ....	In Kimmeridge clay, England, Normandy.
<i>carinatus</i> , Conyb. ....	In oolite, Boulogne
<i>pentagonus</i> , Cuv. ....	Ditto, Ballow, Chaulfour
<i>trigonus</i> ? Cuv. ....	Ditto, Calvados.
<i>macrocephalus</i> , Conyb. ....	In lias, Lyme Regis.
new species, Hawkins ....	Ditto, Somersetshire.

*Family Chelonii.*

<i>Emys</i> , Mantell ....	In the Wealden, Sussex, Jura, Solenhofen.
<i>Chelonia</i> of Glaris, Cuv. ....	In lias, Plattenburg in Glaris
others ....	Stonesfield, Sussex, Solenhofen.

MAMMALIA.

<i>Didelphis Bucklandi</i> , Broderip. ....	{ In Stonesfield slate. Four specimens of the lower jaw exist. They are in the cabinets of Dr. Buckland, Mr. W. J. Broderip, M. C. Prevost, and the York- shire Philosophical Society. The latter specimen was obtained from Stones- field by Mr. Platt, and by him transferred to Sir Christopher Sykes, Bart., in whose collection, now the property of the Rev. C. Sykes, it was discovered by the writer of these pages.
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PISCES.

Name.	British Localities.		Foreign Localities.	
	In Lias.	In Oolites.	In Lias.	In Oolites.
<i>Uraeus gracilis</i> , Agassiz ....			Württemberg.	
<i>Sauropsis latus</i> , Ag. ....			Ditto.	
<i>Ptycholepis Bollensis</i> , Ag. ....			Boll.	
<i>Semionotus leptoccephalus</i> , Ag. ....			Zell, near Boll.	
<i>Lepidotes gugas</i> , Ag. ....			Ohmdern, near Boll.	
<i>frondosus</i> , Ag. ....			Zell.	
<i>ornatus</i> , Ag. ....			Württemberg.	
<i>Leptolepis Brouni</i> , Ag. ....			Near Donaueschingen.	
<i>Jägeri</i> , Ag. ....			Zell.	
<i>longus</i> , Ag. ....			Ditto.	
<i>Tetragonolepis heteroderma</i> , Ag. ....			Ditto.	
<i>semicinctus</i> , Bronn ....			?	
<i>pholidotus</i> , Ag. ....			Ditto.	
<i>Traillii</i> , Ag. ....	England.		South of Germany ?	
<i>altivelis</i> , Ag. ....			Ditto ?	
<i>Dapedium politum</i> , De la Beche	Lyme Regis, &c.			
<i>Fish teeth and palates</i> ....	Ditto, Bath, &c. ....	{ Yorkshire, m. Bath, L. Oxfordshire, L.		
<i>Ichthyoceros</i> ....	Lyme. ....			Normandy, L.
<i>Undescribed fishes</i> ....	Barrow, Whity ....	Portland, u. &c.		

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The following are from the metamorphic lias of Glarus formerly called greywacke slate.

*Zeus Regleysianus*, Bl.  
    *platusa*, Bl.  
    *spinosus*, Bl.  
*Palaorhynchum Glarisianum*.  
*Clupea Scheuchzeri*, Bl.  
    *elongata*, Bl.  
    *megaptera*, Bl.  
*Anenchelum Glarisianum*, Bl.

The following are from the lithographic limestone of Solenhofen, Pappenheim, Mannheim, and Eichstedt.

*Clupra encrasicholoidea*, Germ.  
    *dubia*, Bl.  
    *Knorni*, Bl.  
    *Salmonen*, Bl.  
    *Davidi*, Bl.  
*Pacilea dubia*, Bl. . . . . Anspach ?  
*Atherina Bavarica*, Germ.  
*Esox avirostris*, Germ.  
    *acutirostris*, Bl.  
*Stromateus hexagonus*, Germ.  
*Ichthyolithus esociformis*, Germ.  
    *lucniformis*, Germ.

And species supposed to belong to *cyprinus* ? *perca* ? *squalus*, *zeus* ? *chaetodon* ? *sparus*.

### General Summary.

Plants marine . . . . .	4	These occur in the limestones
terrestrial cryptogamous. . . . .	39	These are found in the sandstones and coal shales. The coal is principally composed of equisetæ.
gymnospermous . . . . .	33	
monocotyledonous, &c. . . . .	4	
<i>Polyparia fibrosa</i> . . . . .	75	<i>Conchifera brachiopoda</i> . . . . . 61
coralliferous and . . . . .	41	<i>Mollusca gasteropoda</i> . . . . . 111
celluliferous . . . . .		<i>cephalopoda</i> . . . . . 273
<i>Radiaria</i> . . . . .	59	<i>Annulosa</i> . . . . . 55
<i>crinoida</i> . . . . .	31	<i>Crustacea</i> . . . . . 22
<i>stellaria</i> . . . . .	7	<i>Insecta</i> . . . . . 40
<i>echinoda</i> . . . . .	47	<i>Fishes</i> . . . . . 40
<i>Conchifera</i> <i>plagymyona</i> . . . . .	189	<i>Reptiles</i> . . . . . 40
<i>mesomyona</i> . . . . .	131	<i>Mammalia</i> . . . . . 1
Total number of species . . . . .	1272	

It is impossible to close this extensive catalogue of the plants and animal remains of the oolitic period without acknowledging the great value of Mr. De la Beche's laborious investigations in this yet inexhausted field. In the German translation of his *Manual of Geology*, for which we are indebted to M. Von Dechen, are many important additions and improvements.

### Cretaceous System.

Mineral  
character.

That a peculiar type, of mineralogical character, belongs to each system of formations, must have been sufficiently evident, through the whole course of our investigation. The gneiss and mica slate system, the clay slate system, the limestones of the carboniferous system, the coloured marls and magnesian limestones of the saliferous system, the oolites, are all resting points for the mind, and amidst a multitude of shades and gradations, strongly impress upon us the distinctive features of the several periods of time at which these so different rocks were in a predominant degree produced.

Mineral characters alone, when rightly used, are in many instances sufficient to determine the Geological relations of even distant regions; and when conjoined with the evidence of organic remains, and controlled by careful survey of the strata above and below, they form a secure groundwork for topographical Geology.

The cretaceous system is equally definite as any of the others with respect to the distinctness of its prevailing

mineral ingredients, and not less characteristically marked by peculiar marine exuviae. Chalk and green sands are terms understood by all the Geologists of Northern Europe; and even on the Southern side of the Alps their representatives may be recognised.

Through England, the ranges of chalk hills form a geographical feature even more important than that of the oolites; for though in general not so elevated, they are less interrupted and more extensive, more uniform in composition, and therefore more identical in aspect. The chalk hills form the first great ridge which is to be crossed from the Eastern side of the Island, and nothing can be more remarkable or instructive than such a journey. On approaching these broad hills from the level or gently undulated plains of the Eastern Counties, or the clay vales of the oolite system, the country changes entirely. The streams run in smoothly sloping valleys, the hills rise with beautiful swells into a long waving outline, seldom broken by a tree, but often capped by an ancient tumulus. Arrived on the summit, we behold a mighty extent of broadly undulated land with abundance of depasturing cattle, but few habitations of men. A variety of plants, eminently characteristic of calcareous soil, force themselves on the attention; flints abound in the fields, chalk is cut through in the roads, the soil is thin, the herbage short, the surface dry, and we feel ourselves in a new physical region.

This impression is confirmed when we observe more carefully the numerous undulations upon the surface of the "wolds;" for all these may be traced into connection as so many ramifications of greater valleys, which themselves often unite, and pursue a considerable course without enclosing even the smallest rill, or showing even the mark of a watercourse. These *dry valleys* descend from their origin in regular slopes, and are clearly the work of water, operating with great force, and for some time, but in the present system of Nature the watery agent has wholly disappeared.

The rains are absorbed as fast as they fall upon this dry surface, and sink to considerable depths in the rock, where they are treasured up in reservoirs to supply the deep wells and the constant springs which issue at lower levels.

In a word, broad, swelling hills, smooth, winding, often dry valleys, and a bare dry, grassy, surface, are the general features of the chalky districts.

This character of surface belongs, as Dr. Lister remarked long ago, to the chalk wolds of Yorkshire, Lincolnshire, Norfolk, Suffolk, Berks, Wilts, Dorset; Hampshire, Surrey, Kent, and Sussex.

The cretaceous system forms properly but one formation. Supposing the whole to be present in a single section, we should have the following general series.

Chalk group.	f.	Upper chalk, with abundance of flints in layers and nodules.
	c.	Lower chalk, with fewer flints.
	d.	Chalk marl, or malm.
Green sand group.	e.	Upper green sand, malm rock, or firestone.
	b.	Gault clay.
	a.	Lower green sand or iron sand.

d and c are sometimes undistinguishable. The lower green sand generally forms a distinct ridge, which may even exceed the chalk in height.

The complete system here presented occurs in many parts of Kent, Sussex, and Hampshire, but generally in other parts of England the sections are modified, so as to present only partial assemblages of the beds, some-

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times one, sometimes another being deficient; and with respect to the malm rock, great differences being observable. Thus, in Wiltshire, where Mr. Smith took the type of this formation, we have the upper green sand remarkably developed; the lower one and the gault are contracted.

Chalk upper	} .....	500 feet.
lower		
Chalk marl .....		100
c. Green, grey, and yellow sand .....		120
Gault .....		50
Lower green sand .....		30

Along the line of chalk hills from the valley of the Thames to Lynn, the upper green sand is almost lost in the chalk marl and gault; green grains being mixed with the former, and still more in the upper layers of the latter. In Bedfordshire, the chalk marl produces a bed of silicious, chalky stone, which may probably be analogous to the firestone of Mesterham in Surrey, which is determined to belong to the upper green sand series. Indeed, the sections along this part of the chalk range are very similar to those of Sussex and Kent.

In Lincolnshire we meet with a new feature, a band of red chalk; at the base of that, thick rock; under this no upper green sand, and generally no gault, but the chalk rests upon a thick series of greenish and ferruginous sands, with included beds of sandy limestone, full of fossils resembling those of the lower green sand of Kent. This country has been very badly represented in all our maps.

In Yorkshire, the cretaceous system consists of

Upper chalk.

Lower chalk and traces of chalk marl.

Red band of chalk.

Gault with green grains passing downwards into Kimmeridge clay, without the intervention of the lower green sand.

From several recent researches abroad it has been thought that the chalk group of England and France is imperfect in the upper terms, and that the well-known Maestricht beds, and the recently investigated Gosau beds, appear to soften the transition from the chalk to the true tertiary strata. If Mr. Webster's observation of a supercretaceous marl in the Isle of Wight belong to this era, analogous deposits are not *absolutely* wanting in England. We shall now trace the history of these several members of the green sand and chalk groups, beginning as usual with the lowest.

In Lincolnshire, the lower green sand is a considerable mass of yellow, often very iron sand, forming, toward the West, poor heaths upon the Kimmeridge clay, exactly like those about Lynn, Amphill, and Godstone. It contains a good deal of bad ochre, very similar to that of Shotover Hill, and lines of oxyde of iron like that of Ryegate. Beds of grey stone, blue within, flat-bedded, sandy, and full of fossils, lie in it, and afford excellent road materials. These are dug at Tealby, Market Stainton, Ludford, Cawkwell, Blustone Heath, Stainton in the Hole, &c. It has considerable resemblance to the Kentish rag, and contains *exogyra sinuosa*, *pecten cinctus*, *plagiostomata*, *serpulae*, *ammonites*, *alcyoniform* bodies, small corals, and many other fossils; but *echini* and *belemnites* appear unknown in it. From these details it is evident that the stratum has all the most decided characters of lower green sand. It is exposed by denudation in the chalk, and also runs on

The lower  
green sand.  
(Syn. Iron  
sand,  
Shanklin  
sands, &c.)

the West of the wolds for a great length by Rasen, Lasington, Linwood, &c. to Louth. The whole thickness is probably 100 feet. These notices are partly derived from personal observation in 1821, but principally from a special visit to the district in 1833 with two friends, Messrs. Dikes and Lee of Hull, who have fully explored it.

As usual in coloured sands, this stratum often contains veins of perfectly white sand. At Lynn this has been found of value for the glass-houses. In Cambridgeshire and through Huntingdonshire, the iron sand forms a narrow course of low hills, but through Bedfordshire and Buckinghamshire it takes a commanding station, forming heathy ridges from Potton to Woburn, and through Buckinghamshire, and Oxfordshire, capping Brickhill and Brill Hills, Shotover Hill, Cunnor Hurst, and Faringdon Clump. In Wiltshire, Spy Park, Bowood, Seend Hill, are capped by these beds, but they are supposed to thin out to the South, and to be lost, until in Blackdown they are probably associated with the upper green sand. In the Isle of Purbeck and the Isle of Wight it is an important rock, and, as observed before, encircles the whole of the Wealden formation of Kent and Sussex.

Through the whole of its range from Cambridgeshire into Wiltshire it is a highly ferruginous sand, with spheroidal or merely irregular concretions of oxyde of iron, frequently enclosing a coarse brown ochre. At Shotover, the fine yellow ochre forms two irregular beds, separated by a thin parting of clay. Fuller's earth also occurs in it in layers in Bedfordshire, especially at Woburn. Grains of green sand abound in some layers of these beds in Bedfordshire and Buckinghamshire, and constitute it a real green sand. Chert layers also are formed in it, and many of the beds assume the aspect of coarse conglomerate, used by the ancient Britons for the making of quern stones or carstones, whence Mr. Smith gave this name as a synonyme of the iron sand. Fossil wood is frequent in these beds. In Bedfordshire its thickness may be stated at 100 feet; in Wiltshire Mr. Lonsdale finds it 30.

In the Isle of Purbeck, the iron sand consists of many beds of quartzose conglomerate and of coarse and fine grained sandstones, containing beds of wood coal. In the Isle of Wight, dark red ferruginous sandstones in the upper part, and alternations of red and yellow ferruginous sands and clays in the lower part, form the substance of all the Southern half of the Island, and contribute much to the beauty of the scenery of the Undercliff.

In its long course around the Wealds of Kent and Sussex, the lower green sand presents, with the general characters noticed above, some local peculiarities of interest. In Leith Hill, its extended plateau makes a commanding feature, and shows a great thickness of brown sands, with abundance of chert, with confluent grains passing into chalcedony, and some alcyonites like those of the Isle of Wight.

The importance of the lower green sand as a geographical feature diminishes as it proceeds round the South side of the Weald, but the Northern range is generally elevated and remarkably continuous by Ryegate, Nutfield, and Maidstone to Hythe and Folkstone. At Ryegate it is almost exactly like the ferruginous rock of Woburn; at Nutfield it produces beds of fuller's earth; from Maidstone to Hythe and Folkstone the sands are in general remarkably, and even excessively,

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rich in green grains and nodules, and contain beds of whitish limestone, sometimes chalky and often cherty, with green grains, considerably rich in ammonites, trochi, cardia, pectens, lutrariæ, exogyra, echinites, and other fossils. These beds may be generally called Kentish rag. Some of them are of a dark grey colour, very hard, full of green grains, and rich in many fossils, some of which are usually found in the upper green sand. The cherty beds of Leith Hill and Haslemere are probably the representatives of these calcareo-silicious layers.

Some of the beds of lower green sand about Folkstone are excessively coarse in the grain, and absolutely crammed with green grains and nodules. The large species of *exogyra* is very frequent, and appears characteristic. The blue marl or gault rests immediately on the sandy beds.

The gault  
or golt.  
Syn. Blue  
Marl of  
Tetworth  
and Folk-  
stone, Mea-  
gous Brick-  
earth,  
Sauth.)

The gault or golt is an argillaceous member of the green sand group, of great interest to the Conchologist, since in Kent, Surrey, Sussex, Wiltshire, Cambridgeshire, and Yorkshire, it yields a most rich supply of molluscan remains, many of them minute and of the greatest beauty. It accompanies the lower green sand around the whole district of the Weald, separates the upper and lower green sand in the Isles of Wight and Purbeck, and follows with the same relations the range of the green iron sand through Wilts and Berks, Buckinghamshire and Bedfordshire, and Cambridgeshire, and appears in Yorkshire without either upper or lower green sands immediately below the chalk. Its average thickness may be fairly estimated at 100 feet, and it universally forms a characteristic narrow valley under the chalk. No remarkable peculiarity of mineralogical aspect or chemical composition distinguishes the gault, except a general tendency to admit green grains into its more sandy portions. It produces a capital brick earth fit for white bricks, in the midland Counties. It is often of a very dark blue, but sometimes of a light grey colour. Near Folkstone it contains in the lower part a remarkable layer of small, irregular, ironstone nodules, every one of which is formed round an ammonite. A similar layer contains similar ammonites at Steppingley Park, Bedfordshire. At Speeton in Yorkshire oval nodules of similar nature generally enclose small specimens of *astacus*. Small belemnites, hamites, ammonites, nuculæ, striated terebratulæ, serpulæ, &c. abound in the gault, and serve admirably to complete the catalogues of fossils of the cretaceous system.

The upper  
green sand.

The upper green sand was first examined in Wiltshire, where it consists of green, grey, and iron sands, immediately subjacent to the chalk, and affording passages for the collected water of that thick deposit downward to the gault. The green grains there assumed to be characteristic of these strata are now known to occur in older sands, (in calcareous grit, for instance,) and in much more recent beds, (as above the chalk frequently,) yet still the greenness of the sands immediately below chalk is a curious general fact. They are, however, quite as often grey or even whitish, with a remarkable tendency in the grains to coalesce into meagre sandstone, sandy chert, and at length semitransparent and chalcedonic chert. These effects are particularly to be observed among specimens of the sponges, and so called alcyonia, which abound in the green sand group. It is easy to understand how so variable a mass of sands placed immediately below the chalk, and clearly in many places (as at Havre) graduating into that calcareous rock, should in several instances become so cretaceous as to be hardly distinguish-

able from the chalk itself. This happens in Bedfordshire, where the Tattenhoe stone appears to be the representative of the upper green sand, in Surrey at Mersham, in Dorsetshire at Beer. Round the Weald of Surrey and Sussex, the malm rock, which is certainly coeval with the Wiltshire green sand, (Murchison,) and also with the Mersham firestone, occasionally shows many green grains, and at Beechy Head (Mantell) changes to nearly the ordinary type of the green sand of Wiltshire. From these considerations we are fully justified in regarding the upper green sand as intimately connected with the lower commonly argillaceous part of the chalk, just as the calcareous grit is with the coralline oolite, and the calciferous sand with the inferior oolite. In particular places, mechanical causes gave a predominance to its sandy character, and in others the abundance of organic exuviae impressed it with a particular zoological type. This mode of viewing it exactly accords with its general character through France, where it is associated with the lower argillaceous chalk under the title of *glauconie crayeuse*. According to this classification, the upper green sand or firestone beds form a nearly continuous base for the chalk from Lynn to Dorsetshire, and round the whole of the Weald of Kent and Sussex, yielding organic remains at intervals.

Chalk marl may be viewed as the next step in the gradation of changes by which we are conducted from the green sand system to the true cretaceous type. It is, in fact, an argillaceous chalk, holding variable quantities of clay and sand, superimposed upon the green sand or malm rock, and gradually changing upwards to the lower chalk. It is, perhaps, observable on the Western slopes of the Yorkshire wolds above the red chalk, but is distinctly traceable below nearly the whole range of the chalk hills from Lynn to Dorsetshire, and round the whole of the Weald, every where closely associated with, and indeed hardly separable from, the malm rock or firestone, and often enclosing, as near Woburn and Folkstone, green grains and fossils of the true upper green sand.

Chalk marl.

Were it not that all such classifications are arbitrary, and only locally exact or valuable, we might conveniently group together the upper green sand and chalk marl divisions, and thus rank together the greatest part of the lower fossiliferous beds of the chalk, which, occasionally argillaceous, stony, or sandy, appear very generally interposed between the true chalk and the continuous lower green sand.

In England, generally, the lower half of the thick mass of chalk is harder, more jointed, and less divided by layers of flint nodules than the upper part. It is often of a greyer colour, and, to a certain extent, distinguishable by a different suite of organic remains. In particular, it appears to contain very few of the stellerida, crinoidea, or echinida, not so many belemnites or terebratulæ, but, on the contrary, yields more ammonites, some hamites, trochites, and other fossils approaching to those of the green sand group below. But the mineralogical character of the lower part of the chalk is liable to great variations. In Yorkshire, three-fourths of the whole mass are hard, and the lower portions are as much traversed by layers of flint nodules, at pretty regular distances, as the upper parts. In the Dover cliffs, beds of soft cretaceous marl divide the chalk without flints into two portions, the upper one yellowish, hard, and containing numerous thin beds of organic remains, the lower one whiter, softer, often gritty at the top, en-

Lower  
chalk.

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chalk.

closing masses of pyrites, but few organic remains. (W. Phillips, in *Geology of England and Wales*.)

The upper chalk is usually recognised in England by its whiteness, softness, numerous layers of flints at intervals of four to six feet, and abundance of zoophytic remains. Sponges of many kinds, small lamelliferous corals, millepores, crinoidea, stellerida, echinida of very remarkable form, large inocerami, belemnites, and abundance of terebratulæ are the most frequent of its numerous fossils. The layers of flint nodules are exceedingly interesting, and throw light upon the mode of formation of the chalk. They are always found in the planes of stratification, generally irregular in figure, black or grey within, with traces of spongiferous bodies, shells, echini, or other organic bodies. The external crust is usually white and silicious. The sponges also are often quite white and silicious, and lodged in a cavity, left by the decay of part of their substance. The crusts of echini are usually, even when enveloped in flint, converted to calcareous spar, and belemnites retain their original radiated structure. Occasionally, as at Sudbury, the flint occurs in thin layers parallel to the stratification.

It seems probable that in the formation of the chalk from the decomposition of the sea-water then holding lime and silica in solution, the carbonate of lime and silica fell to the bottom together, in quantities sufficient on each occasion to constitute a *bed* of chalk and flint, and that the latter substance was especially attracted by the organic remains then lying on or beneath the beds, so as to collect round the sponges, echini, &c., exactly as the oolitic matter has been collected round shells, the lias limestone round ammonites, the carbonate of iron round ferns, &c. Analogous cases occur in the spongiferous cherts of the Portland oolite and coralline oolite, and we might perhaps venture to extend the same mode of reasoning to the case of chert nodules in carboniferous limestone, for these often (not so generally as in the case of flint) contain organic remains.

Pyrites is generally plentiful in the upper chalk, variously crystallized, and is not unfrequently associated with silica in the sponges which lie in chalk. It is in these cases generally decomposed into brown oxide of iron.

Flints are very often split or cracked in their native repositories, as if by contraction of the mass, and this sometimes, but less frequently, happens, when organic remains of a solid kind are enclosed in them. The most remarkable cases of this nature are described by Mr. Webster, in the dislocated upper strata of chalk in the Isle of Wight. "All the flints in the layers which alternate with chalk, are found broken in every direction into pieces of every size, which remain in their relative places enclosed within the cell of chalk, and showing no other signs of fracture than a fine line, as in shivered glass. On being removed from their place the flints fall into many pieces. This singular fact seems connected with the disturbances of the chalk, and may, perhaps, be due to the violence of the tremour then impressed upon the mass, a tremour which might shiver elastic flint, (especially if, like a Rupert's drop, its particles had been previously in a state of tension,) but leave the chalk unaffected.

Mr. Webster's account of a bed of argillaceous chalk or marl in the Isle of Wight, above the chalk with flints, seems to be the only indication of a transition or gradation of deposits between the chalk and the tertiary beds yet clearly observed in England. The marl

dug on the Sussex Downs, as well as that in Hertfordshire and Norfolk, may, perhaps, be related to it.

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### Range of the Cretaceous System out of England.

The principal range of the cretaceous rocks is included within the general boundaries of the European basin, and it is probably not at all less extensive than the oolitic system, though by the diffusion of tertiary rocks above it, its course in large tracts of country is wholly subterranean.

The cretaceous system of Ireland is in a depression, Ireland, on the Western side of what is usually understood by the basin of Europe. It consists of chalk 200 or 300 feet thick, harder than is common in England, but with a similar though less extensive suite of organic remains, and rests on green sand, there called *mulatto*, with the usual characters of that group in England. Lias is found beneath at the Giant's Causeway. In Scotland, only a very dubious indication of the cretaceous system is afforded by the flints which rest upon primary rocks near Peterhead.

Within the natural modern boundaries of the principal basin of European secondary strata, the primary rocks of Scotland, Cumberland, Wales, Cornwall, and Brittany, on the West; the Pyrenæes, the Alps, and the Carpathians, on the South; Caucasus and Oural on the East; Finland and Scandinavia on the North; the cretaceous system, chalky, marly, or sandy, is very largely developed. The type of the formation may be taken in Southern England or Northern France indifferently. In the latter Country its extent on the surface is probably equal to the whole superficial area which it occupies elsewhere in Europe. It encircles with a broad belt the basin of Paris, and passes off on the North-Eastern side into Belgium, which whole Country it probably underlies, though the tertiary deposits conceal it, except along the sides of the Meuse. At Maestricht the upper beds of the cretaceous formation have, in many respects, mineralogical and organic, a remarkable analogy to the *calcaire grossier*, which is the lowest really marine tertiary rock in the vicinity. These beds, however, by their principal characters really belong to the cretaceous system, of which they may be considered the highest terms at present known. A little appearance of the chalk is observable North of the coal of Elberfeld, to which it is unconformed, as well as to that of Namur and Liege. The chalk system most probably underlies the whole region of Northern Germany, from the point last mentioned North of the oolite and lias of Westphalia. The green sand is remarkably well exhibited with characteristic fossils in the romantic tract of Saxony, North of the Erzgebirge, (there called *quadersandstein*;) as well as an upper calcareous portion supposed equivalent to the chalk and planerkalk. North of the Carpathians, both chalk and green sand occur in long ranges of hills, passing from Poland by Lemberg into Podolia and the South of Russia. It reaches the Dnieper, and extends to the plains of Volhynia. It forms considerable eminences around Grodno in Lithuania. Further South, in the plains of Moldavia, Podolia, and Bessarabia, it appears only in detached portions. Chalk is found on the Southern side of the granitic Steppe in the Crimea, and on the borders of the Sea of Azof, between the Berda and the Don. In the Country of the Don Cossacks, in the Governments of Woronack, Koursk, and Toula, it

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appears in hills and on the banks of rivers, and probably constitutes the base of that great and fertile plain." (Pusch, quoted by De la Beche, *Manual of Geology*.)

In Pomerania and Mecklenburg, and the Island of Rugen, cliffs of chalk occur with the usual fossils of England, and in Sweden it rests upon rocks of gneiss and greywacke, and only in one instance, at Limhamn in Scania, upon rocks of the oolitic era. In the North of Germany it appears at intervals, near Lüneburg, and on the borders of the Harz mountains, (at Quedlinburg,) and there seems no reason to doubt that the whole vast plain of Northern Germany, from the Rhine to the Vistula, rests upon the cretaceous system. What remains of the Island of Heligoland consists of green sand.

The whole line of the Alps from the Salève to Vienna is bordered upon the Northern side by rocks of the cretaceous system, which are closely associated in character with both the oolites beneath, and with the tertiaries which lie above. A similar observation applies to the South side of these mountains; chalky rocks range down the Apennines, and occur abundantly in the Maritime Alps, there, as well as about Geneva, intimately associated with the upper oolitic beds. Deposits of this era also lie in old valleys of the Jura mountains, which range in a North-Eastern and South-Western direction. The Pyrenees are bordered on both sides by green sand and sandy and calcareous beds, containing with many chalk fossils some of tertiary types.

Over this extensive area the mineralogical characters of the system are tolerably uniform, except in the vicinity of the Alps, where the violent disturbances to which that mountain range has been subjected appear to have entirely altered the aspect of these beds, so as to permit authors to speak of *black chalk*, which, however, is perhaps a portion of the green sand group. Over all the region already mentioned in France, in Belgium, at all the points in Northern Germany, in Poland, in Russia, Pomerania, Denmark, and Sweden, the chalk has its usual characters and appearance, and contains *ammonites*, *spatangi*, *belemnites*, *terebratula*, *inocerami*, &c. The green sand in France, near Aix la Chapelle, along the Erzgebirge, in Poland, along the Carpathians, in Heligoland, has its usual characters. Indeed, even along the Eastern Alps, out especially in the Swiss and Savoy Alps, and the Jura, the green sands' group retains nearly its usual aspect, and exhibits its usual fossils; and an English Geologist placed at the Perte du Rhône, or amidst the relics of the Montagne de Fiz, is at once introduced to the Geology of the vicinity. Green sand layers alternate with the upper part of the Jura oolites in the Salève, and the same phenomenon appears to happen along the Eastern Alps, (Murchison's and Sedgwick's *Memoirs, Geological Transactions*.) where some parts of this group contain fossils so as to be characterised thereby. Nummulites are associated with the green sand in the Swiss Alps, and also in the Maritime Alps, where the lower beds of the cretaceous formation consist of light-coloured limestone charged with green grains, and full of belemnites, ammonites, nautilus, and pectines, and appear intimately connected with the top of the Jura limestone deposit. (De la Beche, *Manual*, 259.) Nummulitic rocks, calcareous and arenaceous, exist in Dalmatia, and form high mountains in Croatia.

On the Southern side of the Alps, the beds of the cretaceous era, which descend to the plains of Lombardy,

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are principally composed of white, greenish, and reddish beds, and it appears that a gradation of character may be traced through the oolitic, cretaceous, and tertiary strata here uplifted. (Murchison.) Some of the light-coloured limestones referred to the chalk are called scaglia, and the mountain of the Voirons near Geneva, yields a rock of similar nature.

#### *Dislocations of the Cretaceous System.*

Like the oolitic era, the cretaceous period appears to have been one of regular action, perhaps still more uniform than that, but not of so long duration. For we do not find its deposits to contain so many distinct suites of organic remains, nor so many remarkable repetitions of analogous rocks as occur in the oolitic system. The lower sandy beds of the system, indeed, may be thought to have been influenced by the convulsions which upheaved the oolites, but we cannot assent to the notion of Elie de Beaumont, that the whole cretaceous system is derived from the mechanical movements thus impressed upon the waters. The organic remains of the system sufficiently disprove this, and the great extent and uniformity of the deposit of chalk is no otherwise to be explained, than by general laws applicable to all the older and more recent calcareous strata.

That disturbances of great extent happened somewhere after the deposit of the chalk in England, is evident from the extraordinary abundance of sandy and gravelly accumulations, sometimes resting in hollows of the chalk, which immediately cover that stratum. A great part of the plastic clay group is of this fragmentary and tumultuary origin, and its black flint pebbles are only water-worn chalk flints. But England does not appear to have been the centre of these convulsions, nor to have been much moved by them unless bodily, and without local and violent fracture of strata. It is, indeed, very probable, that parts of the chalk formation, originally deposited in deeper seas, were at this time brought up and made to constitute a shore and to be liable to all the waste of the waves. And some portions might be, and probably were, raised to dry land, and exposed to the weather and the wearing of streams. But we cannot at present undertake to say where such a shore occurred, nor in what part exactly the chalk was raised into hills.

In Ireland, at this period, great eruptions of basalt happened, and broad lakes of lava covered the chalk of that Country.

In France the chalk was wasted, as in England, and its flints rolled to pebbles, to constitute the pebbly beds of the plastic clay group; and this seems to have been chiefly effected by fresh-water streams, for we find in the plastic clay of France few organic remains besides terrestrial and fresh-water productions. Yet here, we believe, it is equally difficult to say what portions of the chalk were thus raised and exposed. The surface of the chalk in France appears to have been more wasted and furrowed than in England.

To this period, Elie de Beaumont ascribes the dislocations which in the French Alps and the South-Western extremity of the Jura, from the environs of Antibes to those of Pont d'Ain and Lons le Saulnier, present a series of dislocations in a direction North North-West. The primary mass of Mont Viso is traversed by this system of faults. The Eastern crests of the Devolny on the North of Gap, are formed of the oldest beds of the green sand and chalk, thrown up in the direction

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North North-West, and raised more than 4700 English feet above the sea, while at their feet, and 2000 feet lower, the nummulitic or upper portion of the cretaceous system remains horizontal and entirely undisturbed.

Every thing belonging to this particular epoch, that is calculated to throw light on the changes then operated on the external features of the Globe, is of the highest curiosity and importance, since the probability is great that very violent and extensive convulsions, producing most remarkable alterations in Physical Geography and in other conditions of organic life, must have happened to occasion so entire and sudden a change of plants, shells, and vertebrated animals, as, notwithstanding recent discoveries of supposed intermediate strata, is admitted to have taken place after the deposition of the cretaceous system.

Some time after the above remarks were written, the third volume of Mr. Lyell's *Principles of Geology* appeared, in which that able Geologist has ventured to do what we thought too difficult to attempt, and de-

finer in one instance what part of the ancient bed of the sea was raised at the commencement and during the continuance of the tertiary period. Combining his own observations on tertiary strata with Mr. Mantell's discoveries, he proposes the theory that the elevation of the Wealden district of Sussex and Kent was contemporaneous with, or only immediately antecedent to, the deposition of the tertiary rocks in those parts of the sea which are now become the basins of London and Hampshire; that the elevation of the secondary, as well as the deposition of the tertiary rocks, was produced by long continued operations of the same kind, and that as different strata were raised in the Weald, to be wasted away by the sea and atmospheric action, the tertiary deposits, thence carried to the depths of the sea, were proportionately varied. We cannot now discuss this ingenious theory, because it is connected with a very extensive argument, involving many of the fundamental views of this author, Elie de Beaumont, and Von Buch, but it will be examined in its proper place.

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*Table of the Organic Remains of the Cretaceous System.*

PLANTS. (from M. Adolphe Brongniart.)

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Confervæ	Confervites fasciculata	.....	Sussex	chalk	Arnager in Bornholm.
	agagropoloides	.....		ditto	Ditto.
Algæ	Fucoides Brardi	.....			Palapenson. (Dordogne.)
	Orbignianus	.....			Isle d'Aix, near La Rochelle.
	strictus	.....			Isle d'Aix.
	tuberculosis	.....			Ditto.
	Targionii	chalk	Bognor, Sussex		Les Voirons, near Florence.
	æqualis	.....			Vernasque in the Plaisantin.
	difformis	.....			Bidache, near Bayonne.
	intricatus	.....			Onelle, Genoa, Florence, Vienna, Bidache.
	furcatus	.....			Vernasque, Gênes, Florence.
	recurvus	.....			Vernasque.
	Lyngbianus	.....			Arnager.
	Brongniarti, Mant.	ditto	Sussex.		
Naiades	Zosterites caulimifolia	.....			Isle d'Aix.
	lineata	.....			Ditto.
	Bellovisiana	.....			Ditto.
	elongata	.....			Ditto.
Oycadææ	Cycadites Nilsonii	.....		chalk	Scania.
	Thuytes aliena, Sternb.	.....		planerkalk	Schmetzschna.
	Wood, dicotyledonous	ditto	ditto.		
Leaves resembling	platanus and hriodendron, Sternb.	.....			Blankenburg, Wernigerode.

It does not appear that any of the plants of this epoch were in existence before or since.

POLYPARIA.

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Fibrosæ	Spongia plana, Phil.	chalk	Bridlington.		
	capitata, Phil.	.....	Ditto.		
	osculifera, Phil.	.....	Ditto.		
	convoluta, Phil.	.....	Ditto.		
	lobata, Flem.	.....	Lewes, Norwich.		
	marginata, Phil.	.....	Bridlington.		
	radiciformis, Phil.	.....	Ditto.		
	terebata, Phil.	.....	Ditto.		
	porosa, Phil.	.....	Ditto, Dover.		
	lævis, Phil.	.....	Bridlington.		
	cribrosa, Phil.	.....	Ditto.		
	ramosa, Mant.	.....	Ditto, Sussex		Noirmoutier.
	paradoxa	.....	Hunstanton, Southbourn.		
	(Spongia) labyrinthicus, Mant.	.....	Heytesbury, Lewes.		
	Townsendi, Mant.	.....	Ditto, ditto.		
	(Siphonia) Websteri	green sand.	Isle of Wight, Southbourn.		
	curvicornis, Goldf.	.....		marl	Westphalia.
	incrassata, Goldf.	.....		chalk	Ditto.
	(Ventriculites) Benettii, Mant.	chalk	Lewes, Wilts, Bridlington.		
	radiatus, Mant.	ditto	Lewes.		
	alcyonoides, Mant.	ditto	Ditto, Warminster.		
	quadrangularis, Mant.	ditto	Offham, Sussex.		

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	Fibrosæ ....	(Choanites) subrotundus, } Mant. ....	chalk ....	Lewes.		
		flexuosus, Mant. ....	ditto ....	Ditto.		
		Koenigi, Mant. ....	ditto ....	Warminster, Lewes.		
		Halirrhoa costata, Lam. ....	green sand ....	Warminster ....		Normandy.
		Paramoudra ....	chalk ....	Belfast, Norfolk.		
		Aleyonium globulosum, Defr. ....	ditto ....	Sussex ....		Beauvais, Meudon, &c.
		pyriforme, Mant. ....	ditto ....	Ditto.		
		Serea pyriformis, Lam. ....	green sand.	Warminster.		

Of the following fibrous polyparia described by Goldfuss from Maestricht and Westphalia, it is very probable that when better known, several will be found identical with the spongiæ and aleyoniæ of English authors. It is to be regretted that the labours of Naturalists in this difficult branch of fossil Zoology have been almost fruitless for want of cooperation. The abundance of spongoid fossils is a very remarkable character of the English and Westphalian chalk.

Family.	Name	Rock.	British Localities.	Rock.	Foreign Localities.
	Achilleum glomeratum, ....	Maestricht.		Scyphia Murchisonii ....	Darup.
	fungiforme ....	Ditto.		verticillata ....	Maestricht, Nehou.
	morchella ....	Essen.		mammillaris ....	Essen.
	Manon capitatum ....	Maestricht.		tetragona ....	Ditto.
	tubuliferum ....	Ditto		furcata ....	Ditto.
	pulvinarium ....	Ditto, Essen		foraminosa ....	Ditto.
	peziza ....	Ditto, ditto.		infundibuliformis ....	Ditto.
	stellatum ....	Essen.		Sackii ....	Ditto.
	pyriforme ....	Coesfeld		Tragos deformis ....	Ditto.
	Scyphia fungiformis ....	Ditto.		rugosum ....	Ditto.
	Mantellii ....	Ditto.		pyriforme ....	Ditto.
	Dechenii ....	Ditto.		stellatum ....	Ditto.
	Oeynhausii ....	Darup.		hippocastanum ....	Ditto.
	Carnosa. ....	Chenendopora fungiformis, } Lam. ....	green sand. Warminster.		
		Hippulimus fungoides, Lam. ....	Ditto.		
	Corticifera ...	Gorgonia bacillaris, G. ....	chalk ....	Maestricht.	
		Phil. ....	chalk ....	Bishop's Wilton, Hants.	
	Cellulifera ...	Millepora Fittoni, Mant. ....	ditto ....	Sussex.	
		Gilberti, Mant. ....	Ditto.		
		antiqua? Defr. ....			Normandy.
		Bl. ....			Meudon.
		compressa ....			Maestricht.
		madreporacea ....			Ditto.
	Nullipora racemosa ....				Ditto.
	Eschara cyclostoma ....				Ditto.
		pyriformis ....			Ditto.
		stigmatophora ....			Ditto.
		sexangularis ....			Ditto.
		cuneolata ....			Ditto.
		arachnoides ....			Ditto.
		dichotoma ....			Ditto.
		strata ....			Ditto.
		filigrana ....			Ditto.
		disticha ....			Meudon.
	Cellepora ornata ....				Maestricht.
		hippocrepis ....			Ditto.
		velamen ....			Ditto.
		dentata ....			Ditto.
		costulenta ....			Ditto.
		bipunctata ....			Ditto.
		escharoides ....			Essen.
		Phil. ....	ditto ....	Knapton, Yorkshire.	
	Refepora clathrata ....				Maestricht.
		lichenoides ....			Ditto.
		irregata ....			Ditto.
		disticha ....			Ditto.
		fenestrata ....			Nanta.
		cancellata ....			Maestricht.
	Coscinopora infundibul- } formis. ....			marls. ....	Coesfeld.
		macropora ....		ditto ....	Münster.
	Coeloptychum agaricoides ....			ditto ....	Coesfeld.
	Flustra reticularis, Lam. ....	ditto ....	Sussex, Norwich.		
		reticulata, Desm. ....			Normandy.
		flabelliformis, Lam. ....			Ditto.
		tessellata, Woodw. ....	ditto ....	Norwich.	
	Ceripora cryptopora ....			chalk ....	Maestricht.
		micropora ....			Ditto, Essen, Nanta.
		anomalopora ....			Maestricht.
		polymorpha ....		marl ....	Essen.
		dichotoma ....			Maestricht.
		milleporacea ....			Ditto.



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Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Cellulifera	<i>Ceripora gracilis</i>	.....	.....	.....	Essen.
	<i>madreporacea</i>	.....	.....	chalk.	Maestricht.
	<i>tubiporacea</i>	.....	.....	ditto	Ditto.
	<i>spongites</i>	.....	.....	marl	Essen.
	* <i>clavata</i>	.....	.....	.....	Ditto.
	<i>cribrosa</i>	.....	.....	.....	Ditto.
	<i>verticillata</i>	.....	.....	chalk.	Maestricht.
	<i>spiralis</i>	.....	.....	.....	Ditto.
	<i>pustulosa</i>	.....	.....	.....	Ditto. f
	<i>compressa</i>	.....	.....	.....	Ditto.
	<i>trigona</i>	.....	.....	marl	Essen.
	<i>stellata</i>	.....	.....	chalk	Maestricht, Essen.
	* <i>diadema</i>	.....	.....	.....	Ditto.
	<i>mitra</i>	.....	.....	marl	Essen.
	<i>venosa</i>	.....	.....	.....	Ditto.
	<i>Lunulites cretacea</i> , DeFr.	.....	.....	.....	Maestricht, Tours, Normandy.
	<i>Orbitolites lenticulata</i>	chalk	Sussex.	green sand.	Perte du Rhone.

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Celluliferous polyparia appear at present scarce in the English chalk and green sand, yet probably, on further research, the contrast which in this respect subsists between our series and that of Maestricht and Westphalia may be diminished.

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Lamellifera	<i>Lithodendron gracile</i>	.....	.....	green sand.	Quedlinburg.
	( <i>Caryophyllia</i> ) <i>gibbosum</i>	.....	.....	.....	Near Bochum, Westphalia.
	<i>Caryophyllia centralis</i> , Mant.	chalk	{ Sussex, Yorkshire, Normandy.	.....	.....
	<i>conulus</i> , Phil.	gault	Yorkshire, Cambridgeshire.	.....	.....
	<i>Fungia radiata</i>	.....	.....	chalk	Aix la Chapelle.
	<i>cancellata</i>	.....	.....	.....	Maestricht.
	<i>coronula</i>	.....	.....	marl	Essen.
	( <i>Turbinolia</i> ) <i>Körnigi</i>	{ chalk green sand gault	Sussex. Wilts. Cambridge, Yorkshire.	.....	.....
	<i>Diploctenium cordatum</i>	.....	.....	chalk	Maestricht.
	<i>pluma</i>	.....	.....	.....	Ditto.
	<i>Meandrina reticulata</i>	.....	.....	ditto	Maestricht.
	<i>Astræa flexuosa</i>	.....	.....	.....	Ditto.
	<i>geometrica</i>	.....	.....	.....	Ditto.
	<i>clathrata</i>	.....	.....	.....	Ditto.
	<i>escharoides</i>	.....	.....	.....	Ditto.
	<i>textilis</i>	.....	.....	.....	Ditto.
	<i>velamentosa</i>	.....	.....	.....	Ditto.
	<i>gyrosa</i>	.....	.....	.....	Ditto.
	<i>elegans</i>	.....	.....	.....	Ditto.
	<i>angulosa</i>	.....	.....	.....	Ditto.
	<i>geminata</i>	.....	.....	.....	Ditto.
	<i>arachnoides</i>	.....	.....	.....	Ditto.
	<i>rotula</i>	.....	.....	.....	Ditto.
	<i>macrophthalma</i>	.....	.....	.....	Ditto.
	<i>muricata</i>	.....	.....	.....	Mendou.
	<i>stylophora</i>	.....	.....	.....	Ditto.
	<i>Pagrus Proteus</i> , DeFr.	.....	.....	.....	Ditto. Tours, Normandy.

It is probable that the whole suite of polyparia of the cretaceous system is peculiar to it. This remark is meant to apply to the Maestricht fossils as well as to the more generally recognised types of chalk and green sand.

## RADIARIA.

Family.	Name.	Rock.	Foreign Localities.	Rock.	British Localities.
Crinoidea	<i>Apiocrinus ellipticus</i>	chalk	{ Sussex, Wiltshire, York- shire	chalk	Touraine, Normandy.
	<i>Pentacrinus caput Medusæ</i>	gault	Yorkshire	ditto	Maestricht.
	<i>Marsupites Milleri</i> , Mant.	chalk	Ditto, Wiltshire, Sussex.	.....	.....
	<i>Glenotremites paradoxus</i> , G.	.....	.....	marl	Speldorf, near Mulhausen.
Stelleriæ	<i>Asterias quinqueloba</i>	.....	.....	chalk	Maestricht, near Münster.
	.....	ditto	Norwich, Wiltshire.	.....	Paris, Rouen, &c.
	<i>regularis</i> , Wood.	.....	Swaffham, Lewes.	.....	.....
	<i>semilunatus</i>	ditto	{ Norfolk, Wiltshire, York- shire.	.....	.....
Echinida	<i>lentiginosus</i> , Wood.	.....	Dover.	.....	.....
	<i>Cidaris regalis</i>	.....	.....	ditto	Maestricht.
	<i>scutigera</i>	.....	.....	.....	Kehlheim, Bavaria.
	<i>crenularis</i>	.....	.....	.....	France.
	<i>granulosa</i>	.....	.....	.....	Aix, Maestricht, Essen.
	<i>variolaris</i>	.....	.....	marl	Essen, Cocfeld.
	<i>ornata</i>	.....	.....	.....	Essen.
	<i>papillata</i> , Park.	ditto	{ Wiltshire, Sussex, York- shire.	.....	.....
	<i>mammillata</i> , Park	.....	Wiltshire.	.....	.....
	<i>cretosa</i> , Mant.	.....	Lewes, Northfleet.	.....	.....

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	Echinida...	<i>Cidaris variolaris</i> (G. Trans.)	.....	Lewes, Lyme.	chalk	Havre.	
		<i>vulgaris</i> , Lam.	.....	.....	.....	Poland.	
		<i>asterizans</i> .....	green sand.	Warminster.	.....	.....	
		<i>corollaris</i> , Mant.	chalk	Sussex, Wiltshire, &c.	.....	.....	
		<i>clavigera</i> , Koenigi	.....	Sussex.	.....	.....	
		<i>vesiculosa</i> .....	.....	.....	marl.	Essen.	
	<i>Echinus</i>	<i>saxatilis</i> , Park	ditto	Sussex, Norwich.	.....	.....	
		<i>Koenigi</i> , Mant.	.....	Sussex, Yorkshire	.....	Moen.	
		<i>Benettii</i> , Koenigi	green sand.	Wiltshire.	.....	.....	
		<i>areolatus</i> , Wahl.	.....	Ditto, Lyme Regis	chalk	Rodsborg in Scania.	
		<i>alvaceus</i> .....	.....	.....	marl.	Essen.	
		<i>granulosus</i> .....	.....	.....	sandstone.	Kuhlheim.	
		<i>radiatus</i> .....	.....	.....	marl.	Essen.	
		<i>Clypeus</i> , small species	ditto	Warminster.	.....	.....	
	<i>Clypeaster</i>	<i>Leskii</i> .....	.....	.....	chalk	Maestricht.	
		<i>fornicatus</i> .....	.....	.....	.....	Munster.	
	<i>Galerites</i>	<i>albogalerus</i> , Leske	chalk	Lewes, Wiltshire, Yorkshire	ditto	Aix, Poland, Dieppe, &c.	
		<i>subrotundus</i> , Leske	.....	Lewes, Norwich, Yorkshire.	.....	.....	
		<i>vulgaris</i> , Lam.	.....	Lewes, Lyme.	.....	Aix, Dreux.	
		<i>conoideus</i> .....	.....	.....	ditto	Perigord.	
		<i>subuculus</i> , Lam.	.....	Wiltshire	{ green sand and marl }	Havre, Coesfeld, and Essen.	
		<i>depressus</i> , Lam.	.....	.....	.....	Fiz, Swisserland, Bavaria.	
		<i>canaliculatus</i> .....	.....	.....	.....	Buren and Brunken, Paderborn.	
		<i>sulcato radiatus</i> .....	.....	.....	chalk	Maestricht.	
		<i>Hawkinsii</i> , Mant.	ditto	Sussex.	.....	.....	
		<i>abbreviatus</i> .....	.....	.....	.....	Aix la Chapelle, Quedlinburg.	
	<i>Echinoneus</i>	<i>subglobosus</i> .....	.....	.....	ditto	Maestricht.	
		<i>placenta</i> .....	.....	.....	.....	Ditto.	
		<i>lampas</i> , De la Beche	green sand.	Lyme Regis.	.....	.....	
		<i>peltiformis</i> , Wahl.	green sand.	.....	.....	Scania.	
	<i>Nucleolites</i>	<i>depressus</i> .....	.....	.....	ditto	Aix la Chapelle?	
		<i>ovatus</i> , Lam.	.....	.....	.....	Maestricht.	
		<i>scrobiculatus</i> , Lam.	.....	.....	.....	Ditto.	
		<i>pyriformis</i> .....	.....	.....	.....	Ditto.	
		<i>lacunosus</i> .....	.....	.....	marl.	Essen.	
		<i>cordatus</i> .....	.....	.....	.....	Ditto.	
		<i>carinatus</i> .....	.....	.....	chalk	Aix, Hildesheim, Essen.	
		<i>lapis caneri</i> .....	.....	.....	.....	Aix, Maestricht.	
		* <i>testudinarius</i> .....	.....	.....	.....	Ratisbon.	
		<i>rotula</i> , Bt.	.....	.....	.....	Rouen, green sand, Mtn. de Fiz.	
		<i>castanea</i> , Bt.	.....	.....	green sand.	Mtn. de Fiz.	
		<i>patellaris</i> .....	.....	.....	chalk	Maestricht.	
	<i>Ananchytes</i>	<i>ovatus</i> , Lam.	chalk	{ Sussex, Wiltshire, Nor- wich, Yorkshire, &c. }	ditto	{ Meudon, Sweden, Lublin chalk, marl, Essen.	
		<i>hemisphaerious</i> , Mant	.....	Sussex, Yorkshire.	.....	.....	
		<i>intumescens</i> , Phil.	.....	Yorkshire.	.....	.....	
		<i>pustulosus</i> , Lam.	.....	Norfolk	ditto	Paris, Rouen, Moen.	
		<i>conoideus</i> .....	.....	.....	.....	Aubel in Limburg.	
		<i>striatus</i> .....	.....	.....	.....	Aix, Maestricht.	
		<i>corculum</i> .....	.....	.....	marl.	Coesfeld.	
		other species, Smith	ditto	England.	.....	.....	
	<i>Spatangus</i>	<i>ornatus</i> , Cuv.	green sand.	Lyme	.....	Aix, Biaritz, near Bayonne.	
		<i>suborbicularis</i> , DeFr.	.....	Ditto	.....	Maestricht, Dives.	
		<i>argillaceus</i> , Phil.	gault	Wiltshire, Yorkshire.	.....	.....	
		<i>Murchisonianus</i> , Mant.	green sand.	Norsted, Southbourn.	.....	.....	
		<i>cordiformis</i> , Mant.	chalk	Middleham, Norwich.	.....	.....	
		<i>postratus</i> .....	.....	Brighton, Norfolk	.....	Joigny.	
		<i>prunella</i> , Lam.	.....	Brighton	.....	Maestricht.	
		<i>cor angustum</i> , Lam.	.....	Norwich, Lewes, Lyme, &c.	.....	{ Paris, Normandy, Burgundy, Fiz, Coesfeld, Saxony, Bohemia.	
		<i>planus</i> , Mant.	.....	Yorkshire, Sussex	.....	Scania, Poland.	
		<i>hemisphaericus</i> , Phil.	.....	Yorkshire.	.....	.....	
		<i>laevis</i> , DeFr.	ditto	Lyme	green sand.	Perte du Rhone.	
		<i>bulb.</i> , Bt.	.....	.....	chalk	Paris, Normandy, Maestricht.	
		—, Phil.	green sand.	Chute Farm, Wiltshire.	.....	.....	
		<i>granulosus</i> .....	.....	.....	ditto	Maestricht.	
		<i>subglobosus</i> , Leske	.....	.....	.....	Quedlinburg, Buren.	
		<i>nodulosus</i> .....	.....	.....	.....	Essen.	
		<i>radiatus</i> , Lam.	.....	.....	.....	Maestricht.	
		<i>bicordatus</i> .....	.....	.....	.....	Mecklenburg.	
		<i>truncatus</i> .....	.....	.....	.....	Maestricht.	
		<i>Bucklandi</i> .....	.....	.....	marl	Essen.	
		<i>arcuarius</i> , Lam. a re cent species }	.....	.....	chalk	Maestricht.	
		<i>amygdala</i> , Lin.	.....	.....	.....	Ditto.	
		<i>gibbus</i> , Lam.	.....	.....	.....	Paderborn.	
		<i>cor testudinarium</i> .....	.....	.....	.....	Maestricht, Quedlinburg, Coesfeld.	
		<i>bucardium</i> .....	.....	.....	.....	Aix.	
		<i>lacunosus</i> , Lin.	.....	.....	.....	Aix, Quedlinburg.	
		<i>retusus</i> , Park.	ditto	Wilts.	.....	.....	
		<i>punctatus</i> , Park	.....	Ditto.	.....	.....	

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The distinctness of the form and characters of the incrustated radiaria, permits in general a satisfactory decision concerning their specific identification. On this account, no less than from the general diffusion of these fossils, the echinida, stellerida, and crinoidea ought to afford the most certain evidence concerning the laws of geographical distribution of animals during the cretaceous epoch. It cannot escape notice that a great number of species of echinida belong to extinct genera. It is remarkable that the genus spatangus, of which one or two species occur in oolite and several

exist in the present seas, seems to have arrived at its maximum of abundance in the cretaceous epoch; and that the extinct genus, ananchytea, which is especially abundant and widely diffused in chalk, has not been found in the subjacent oolites, nor in the true tertiaries above the Maestricht beds. It is possible that amongst the echinida a very few species are identical with some found in the oolitic strata, (as galerites depressus, cidaris variolaris, &c.) but in general the species appear to be decidedly peculiar.

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## CONCHIFERA.

Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities.
Plagmyona	Fistulana pyriformis, Mant.	gault.	Willington, Sussex.		
	personata, Mant.	chalk	Sussex.		
	Pholus constricta, Phil.	gault.	Yorkshire.		
	Teredo ? ——— Hæn.			chalk	Maestricht.
	Pholadomya decussata, Phil.	ditto	Speeton; chalk Sussex.		
	Cardium decussatum, Sow.				
	Panopæa plicata	green sand.	Sandgate	green sand.	Osterfeld.
	Mya mandibula		{ Sussex, Isle of Wight, Devizes.		
	depressa	gault.	Yorkshire.		
	phasolima, Phil.		Ditto.		
	plana			ditto.	Ditto.
	—— ? Lonsdale.	chalk	Near Calne.		
	Lutraria striata	green sand.	Lyme.		
	carinifera	chalk.	Ditto.		
	gurgitis, Bt.			ditto	Perte du Rhone, Sweden.
	Amphidesma — Phil. M.S.	green sand.	Hythe.		
	Corbula striatula	ditto	Parham, Pulborough.		
	gigantea		Blackdown.		
	laevigata		Ditto.		
	elegans		Ditto.		
	punctum, Phil.	gault.	Ditto.		
	caudata, Nils.				Köping.
	anatina, Desh.			ditto.	Schonen, Hæn.
	Crassatella latissima, Hæn.			chalk	Maestricht.
	Tellina æqualis, Mant.	green sand.	Parham.		
	inaequalis		Ditto, Blackdown.		
	striatula		Blackdown.		
	—— Phil.	gault.	Yorkshire.		
	Lucina sculpta, Phil.		Ditto.		
	laevis, Phil.		Ditto.		
	Crassina				
	Astarte. } atria		Blackdown, Devizes.		
	Thetis major	green sand	Blackdown, Sussex, Devizes.		
	minor		Sussex, Isle of Wight, &c.		
	Venus angulata	ditto	Blackdown, Parham.		
	caperata		Lyme, Blackdown.		
	ovalis		Parham.		
	fabia		Parham, Isle of Wight.		
	parva		{ Lyme, Isle of Wight, Sussex.		
	lineolata		Blackdown.	green sand.	Bochum.
	plana		Ditto.		
	Ringmeriensis, Mant.	chalk.	Ringmer, Middleham.		
	Cardium Hillanum	green sand.	Blackdown.		
	proboscideum		Near Collumpton, Devon.		
	umbonatum		Blackdown.		
	granulosum, Woodw.	chalk.	Norwich.		
	bullatum, Lam.			chalk.	Aix la Chapelle.
	Cardita Esmarkii, Nils.				Scania.
	tuberculata	green sand.	Devizes, Lyme.		
	modiolus, Nils.			Ditto.	
	crassa			ditto.	Doué.
	Isocardia angulata, Phil.	gault.	Yorkshire.		
	Trigonia spinosa	green sand.	{ Blackdown, Pulborough, Lyme.		
	dædalea		{ Parham, Haldon, &c. Isle of Wight.		
	aliformis		{ Pulborough, Eddington, Wilts.		Altenberg.
	eccentrica		Pulborough, Lyme, Blackdown.		
	spectabilis		Blackdown.		

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	Plagymyona	Trigonia rugosa			green sand.	Perte du Rhone.
		scabra		Lyme		Rouen, Perte du Rhone.
		affinis		Parham, Haldon.		
		pennata		Teignmouth.		
		nodosa		Hythe.		
		pumila, Nils.				Köping, Balsberg.
		arcuata, Lam.				Aix la Chapelle.
	Cucullæa	decussata	green sand.	Parham, Feversham.	chalk.	Rouen.
		glabra.	ditto.	Lyme, Blackdown.		
		carinata	ditto.	Ditto, ditto.		
		fibrosa	ditto.	Ditto, ditto.		
		costellata	ditto.	Lyme, Collumpton.		
		auriculifera, Hæn.			ditto.	Beauvais.
		crassatina			ditto.	Ditto.
			chalk.	{ Sussex, (Mant.) Yorksh. (Phil.)		
	Arca	carinata	green sand.	Devizes, Lyme, Nursted.		
		subacuta		Hainsey		Maestricht.
		exaltata, Nils.				Carlshamen, Sweden, Aix la Chapelle.
		rhomben, Nils.				Balsberg, Sweden.
		ovalis, Nils.				Köping, Scania.
		clathrata, Hæn.				Angers, Saumur.
	Pectunculus	sublævis	ditto.	Blackdown.		
		umbonatus	ditto.	Haldon.		
		lens, Nils.				Balsberg, Köping, Sweden.
	Nucula	impressa	ditto.	Parham, Blackdown.		
		antiquata	ditto.	Parham.		
		angulata	ditto.	Blackdown.		
		ovata, Mant.	gault.	Ringmer, Folkstone, Yorks.		
		subrecurva, Phil.		Yorkshire.		
		pectinata, Mant.		Sussex		Boulonnais.
		undulata		Folkstone.		
		producta, Nils.				Kanberga, Scania.
		truncata, Nils.				Ditto, ditto.
		panda, Nils.				Ditto, ditto.
	Modiola	parallela	green sand.	Maidstone.		
		*bipartita	ditto.	Parham Park.		
		*aqualis	ditto.	Ditto.		
		*pallida		Fonthill, Wilts.		
	Mytilus	lanceolatus	ditto.	Blackdown, Parham.		
		edentulus	ditto.	Blackdown.		
		lævis, Defr.			ditto.	Bouguval, Paris.
		problematicus, Hæn.			green sand.	Bochum.
	Pachyma	grigas	chalk.	Lyme.		
	Mytiloides	labiatus, Schl.	ditto.	Wilts		Aix la Chapelle, Quedlinburg.
Mesomyona	Pinna	tetragona	green sand.	Devizes.		
		gracilis, Phil.		gault.		Yorkshire.
		subcata, Woodw.	chalk.	Norwich.		
		affinis, Hæn.			chalk.	Near Saumur.
		flabellum, Hæn.				Bochum.
		nobilis, Hæn.				Ditto.
		restituta, Hæn.				Valkenburg.
		quadri-valvis, Hæn.				Cotentin, Saumur.
	Gervillia	*aviculoides	green sand.	Parham, Petersfield.		
		*acuta	ditto.	Parham.		
		solenoides	ditto.	{ Ditto, Isle of Wight, Wilts. }		Maestricht, Normandy.
	Clavicularia	serulescens, Nils.				Sweden.
			Mant. chalk.	Sussex.		
	Crenatula	producta.		Sheffield, Bedfordshire.		
		*ventricosa				Bochum. (Hæn.)
	Inoceramus, in-					
	cluding Ca-	*gryphæoides		Lyme, Ringmer.		
	tillus, Cuv.			{ Folkstone, Ringmer, Cam- bridge }		Perte du Rhone, Fiz, Scania.
		*sulcatus		Hainsey.		
		tenuis		Ditto.		
		Crispæ		Folkstone, Lyme, &c.		Perte du Rhone, Essen.
		concentricus		Guildford.		
		pictus		Royston, Lewes, Yorkshire.		Rouen, Tours, Scania.
		Cuvieri	ditto.	Lewes, Yorkshire		Quedlinburg, Poland, Scania.
		Brongniarti	ditto.	Hunmanby.		
		cranium, Phil.	ditto.	Gravesend.		
		cordiformis	ditto.	Norwich, Wilts, Sussex.		
		mytiloides	ditto.	Wilts, Lewes.		
		striatus, Mant.	ditto.	Sussex, Dover.		
		Lamarckii, Mant.	ditto.	Lewes, Heytesbury.		
		undulatus, Mant.	ditto.	Sussex.		
		Websteri, Mant.	ditto.	Ditto.		
		latus, Mant.	ditto.	Ditto, Norfolk.		
		involutus	ditto.	Ditto, Norfolk.		

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Family.	Name.	Rock.	British Localities.	Rock.	Foreign Localities
Mesomyona.	<i>Inoceramus digitatus</i> . . . . .	chalk . . . . .	Essex.		
	<i>rugosus</i> , Hæn. . . . .				Quedlinburg.
<i>Exogyra</i>	<i>haliotidea</i> . . . . .	green sand.	Wilts.		Scania, Essen.
	<i>conica</i> . . . . .	ditto . . . . .	Ditto, Sussex, Blackdown.		Scania.
	<i>recurvata</i> . . . . .	ditto . . . . .	Haldon.		
	<i>plicata</i> . . . . .	ditto . . . . .	Ditto.		
	<i>canaliculata</i> . . . . .	ditto . . . . .	Wilts.		
	<i>undata</i> . . . . .	ditto . . . . .	Blackdown.		
	<i>cornuarietis</i> , Nils. . . . .				Ditto.
<i>Gryphaea</i>	<i>laciniata</i> , Nils. . . . .				Ditto.
	<i>sinuata</i> . . . . .		Isle of Wight, Yorksh. Kent.		Grande Chartreuse.
	<i>vesiculosa</i> . . . . .	ditto . . . . .	Wilts, Sussex	green sand.	Bouches du Rhone.
	<i>columba</i> , Lam. . . . .		Lyme, Longleat . . . . .		Havre, Poland, Saxony.
	<i>globosa</i> . . . . .	chalk . . . . .	Norwich, Lewes, &c.		Perte du Rhone.
	<i>aquila</i> , Bt. . . . .				{ Perigueux, Poland, Grande Char-
	<i>auricularis</i> , Bt. . . . .			chalk . . . . .	treuse, Vauchise.
<i>Sphæra</i>	<i>plicata</i> , Lam. . . . .			green sand.	Boesingfeld; chalk, Saumur.
	<i>truncata</i> , Goldf. . . . .				Maestricht.
	<i>corrugata</i> . . . . .	green sand.	Isle of Wight.		
	<i>Ostræa vesicularis</i> , Lam. . . . .	chalk . . . . .	Sussex, Norwich, &c. . . . .	chalk . . . . .	Meudon, Maestricht, Scania.
	<i>semiplana</i> , Mant. . . . .	ditto . . . . .	Sussex.		
	<i>canaliculata</i> . . . . .	ditto . . . . .	Ditto, Norfolk.		
	<i>carinata</i> . . . . .	green sand.	Wilts, Lyme, &c. . . . .	green sand.	Normandy, Boulogne, Bochum.
<i>Ostræa</i>	<i>macroptera</i> . . . . .		Folkstone.		
	<i>aliformis</i> , Woodw. . . . .	chalk . . . . .	Norwich.		
	<i>tricarinata</i> , Woodw. . . . .	ditto . . . . .	Ditto.		
	<i>digitata</i> , Woodw. . . . .	ditto . . . . .	Ditto.		
	<i>serrata</i> , DeFr. . . . .			chalk . . . . .	Sweden, Maestricht, Dreux.
	<i>lateralis</i> , Nils. . . . .				Scania, Essen.
	<i>clavata</i> , Nils. . . . .				Sweden.
	<i>hippopodium</i> , Nils. . . . .				Ditto.
	<i>*acuminata</i> . . . . .				Scania.
	<i>curvirostris</i> , Nils. . . . .				Ditto.
	<i>flabelliformis</i> , Nils. . . . .				Sweden, Essen.
	<i>pusilla</i> , Nils. . . . .				Scania.
	<i>lunata</i> , Nils. . . . .				Ditto.
	<i>parasitica</i> , Hæn. . . . .			green sand.	Bochum.
	<i>truncata</i> , Hæn. . . . .			ditto . . . . .	Griesenbeck.
<i>Pecten</i>	<i>quinquecostatus</i> . . . . .	chalk . . . . .	{ Sussex; green sand, Blackdown, Lyme, Wilts. }	chalk . . . . .	{ Meudon, Saumur; green sand, Perte du Rhone, Sweden.
	<i>quadricostatus</i> . . . . .	green sand.	Sussex, Blackdown, Wilts.	ditto . . . . .	{ Maestricht, Normandy, green sand, Grande Chartreuse, Saxony.
	<i>Beaveri</i> . . . . .	chalk . . . . .	Sussex.		
	<i>triplicatus</i> , Mant. . . . .	ditto . . . . .	Ditto.		
	<i>orbicularis</i> . . . . .	ditto, &c. . . . .	Ditto, Wilts . . . . .		Sweden, Aix la Chapelle.
	<i>obliquus</i> . . . . .	green sand.	Ditto, ditto.		
	<i>asper</i> . . . . .	ditto . . . . .	Wilts . . . . .		Poland, Bochum, Hatteren.
	<i>mutidus</i> , Sow. . . . .	} chalk . . . . .	Norwich, Brighton . . . . .		Havre, Aix la Chapelle.
	<i>intextus</i> , Bt. . . . .				
	<i>radiatus</i> , Woodw. . . . .	ditto . . . . .	Norwich.		
	<i>sexcostatus</i> , Woodw. . . . .	ditto . . . . .	Ditto.		
	<i>concentricus</i> . . . . .	ditto . . . . .	Ditto.		
	<i>septemplicatus</i> , Nils. . . . .				Scania.
	<i>cretosus</i> , DeFr. . . . .				Paris.
	<i>arachnoides</i> , DeFr. . . . .				Ditto, Normandy.
	<i>membranaceus</i> , Nils . . . . .				Scania.
	<i>dentatus</i> , Nils. . . . .				Ditto.
	<i>extextus</i> , Bt. . . . .				Havre, Normandy, Angers.
	<i>sergatus</i> , Nils. . . . .				Sweden.
	<i>multicostatus</i> , Nils. . . . .				Ditto.
	<i>undulatus</i> , Nils. . . . .				Scania.
	<i>subaratus</i> , Nils. . . . .				Sweden.
	<i>pulchellus</i> , Nils. . . . .				Ditto.
	<i>lineatus</i> , Nils. . . . .				Ditto.
	<i>virgatus</i> , Nils. . . . .				Ditto.
	<i>lævis</i> , Nils . . . . .				Ditto, Aix la Chapelle.
	<i>inversus</i> , Nils . . . . .				Sweden.
	<i>aserrimus</i> , Hæn. . . . .			green sand.	Hardt.
	<i>gracilis</i> , Hæn. . . . .				Aix la Chapelle.
	<i>gryphæatus</i> , Hæn. . . . .				Ditto.
	<i>regularis</i> , Schl. . . . .			chalk . . . . .	Maestricht.
	<i>reticatus</i> , Hæn. . . . .				Ditto; green sand, Hardt.
	<i>versicostatus</i> , Hæn. . . . .			green sand.	Aix la Chapelle, Miunden.
<i>Plagystoma</i>	<i>spinosum</i> . . . . .	chalk . . . . .	Sussex, Wilts . . . . .	ditto . . . . .	France, Poland, Saxony, Sweden.
	<i>Hoperi</i> , Mant. . . . .	ditto . . . . .	Ditto.		
	<i>Brightonense</i> , Mant. . . . .	ditto . . . . .	Ditto.		
	<i>elongatum</i> . . . . .	ditto . . . . .	Ditto.		
	<i>asperum</i> , Mant. . . . .	ditto . . . . .	Ditto.		
	<i>? pectinoideum</i> . . . . .			ditto . . . . .	Perte du Rhone.
	<i>ovatum</i> , Nils. . . . .				Sweden.

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	Mesomyona	Plagiostoma semisulcatum, Nils. ....				Sweden, Saumur.	
		Mantelli, Bt. ....	chalk	Dover		Denmark.	
		granulatum, Nils. ....				Sweden.	
		elegans, Nils. ....				Ditto.	
		pusillum, Nils. ....				Ditto.	
		turgidum, Lam. ....			chalk	Saintes; green sand, Osterfeld.	
	Podopsis or Dianchora	lata, chalk	Sussex.				
		obliqua, Mant. ....	ditto	Ditto.			
		striata, ....	ditto	Yorkshire		Havre, Essen, Bochum.	
		truncata, Lam. ....		Lyne	ditto	Normandy, Touraine, Sweden.	
		lamellata, Nils. ....				Sweden.	
	Plicatula	inflata, ditto	Sussex; green sand, Wilts.				
		pectenoides, ....	ditto	Sussex; gault, Cambridge.			
	Spondylus ?	strigilis, Bt. ....			green sand	Perte du Rhone.	
Rudista	Sphærolites	dilatata, Des			chalk	Royan, Talmont, mouth of the Gironde.	
		Moulini, ....				Royan, Talmont, Vallée de la Couze, Dordogne.	
		Bournonii, Des M. ....			ditto	Royan, Talmont.	
		ingens, Des M. ....			ditto	Ditto, ditto, Languais, Dordogne.	
	Hanninghausi, Des M.	foliacea, Lun. ....			ditto	Isle d'Aix.	
		Jodana, Des M. ....			ditto	Mirambeau, Charente Inférieure.	
		Jeuanneti, Des M. ....			ditto	Vallée de la Couze, Perigord.	
		crateriformis, Des M. ....			ditto	Royan, Languais.	
		Moulini, Goldf. ....			ditto	Maestricht.	
	Hippurites	radiosa, Des M. ....			ditto	Cendneux, Perigord.	
		cornu pastoris, Des M. ....			ditto	Pyles, Perigueux.	
		striata, Defr. ....			ditto	Alet, Aude.	
		sulcata, Defr. ....			ditto	Ditto, ditto.	
		dilatata, Defr. ....			ditto	Ditto, ditto.	
		bioculata, Lam. ....			ditto	Ditto, ditto.	
		fistula, Defr. ....			ditto	Ditto, ditto.	
		undetermined			ditto	In Sussex chalk. (Mantell.)	
Brachiopoda	Terebratula	subrotunda, chalk	Sussex, Norwich, &c.	green sand	Bochum.		
		carnea, ditto	Norwich, Sussex	ditto	Bochum; chalk, Meudon.		
		ovata, ditto	Sussex; green sand, Sussex	ditto	Bochum, Scania.		
		undata, ditto	Sussex.				
		elongata, ditto	Ditto.				
		biplicata, green sand	Ditto, Wilts, Cambridge.				
		lata, ditto	Sussex, Devizes.				
		subundata, chalk	Yorkshire	chalk	Rouen.		
		plicatilis, ditto	Norwich, Sussex, Gravesend	ditto	Meudon, Moen; green sand, Grande Chartreuse.		
		subplicata, Mant. ....	Sussex, Yorkshire, Wilts.	ditto	Tours, Beauvais, Maestricht.		
		Mantelliana, ditto	Sussex.				
		rostrata, ditto	Ditto.				
		Martini, Mant. ....	Ditto.				
		squamosa, Mant. ....	Ditto.				
		pentagonalis, Phil. ....	Yorkshire.				
		lineolata, Phil. ....	gault	Speeton, Yorkshire.			
		De-franci, Bt. ....	chalk & gault	Sussex, Yorkshire		Meudon, Sweden, Maestricht.	
		alata, Lam. ....			ditto	Meudon, Sweden.	
		octoplicata, ....			ditto	Dieppe, Sweden; green sand, Quedlinburg.	
		gallina, Bt. ....	chalk	Norwich	green sand	Perte du Rhone, Normandy.	
		ornithocephala, ....			ditto	Perte du Rhone, Fz	
		pectinata, ....	green sand	Wilts.		Normandy; Havre, Scania.	
		lyra, ditto	Ditto				
		semiglobosa, ....	chalk	Yorkshire		Sweden, Moen, Bochum.	
		obtusa, ....	green sand	Cambridge	ditto	Quedlinburg.	
		obesa, ....	chalk	Warminster	chalk	Biinde Kündert.	
		dimidiata, ....	green sand	Haldou, Wilts.	green sand	Havre.	
		ovipeda, ....			ditto	Bochum.	
		curvirostris, Nils. ....				Scania.	
		recurva, Defr. ....				Maestricht, Normandy.	
		longirostris, Wuhl. ....				Scania.	
		rhomboidalis, Nils. ....				Sweden.	
		triangularis, Wuhl. ....				Scania.	
		longirostris, Wuhl. ....				Sweden.	
		aperturata, Schl. ....			chalk	Essen.	
		chrysalis, Schl. ....			ditto	Maestricht.	
		curvata, Schl. ....			green sand	Quedlinburg.	
		dissimilis, Schl. ....			chalk	Speldorf; green sand, Bochum.	
		lacunosa, Schl. ....			green sand	Quedlinburg.	
		microscopica, Fond. ....			chalk	Maestricht.	
		nucleus, Defr. ....			green sand	Bochum, Quedlinburg.	
		peltata, Hæn. ....			chalk	Maestricht.	
		semistriata, Lam. ....			green sand	Bochum.	
		varians, Hæn. ....			chalk	Essen.	
		vermicularis, Schl. ....			ditto	Maestricht.	

Geology. Ch. II.	Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.	Geology. Ch. II.
	Brachiopoda	<i>Terebratula ? vitrea</i> , Lam.	green sand.	Hythe.	chalk	Essen.	
		<i>sella</i>	ditto	Faringdon.			
		<i>depressa</i>	ditto	Ditto.			
		<i>nuciformis</i>	ditto	Sandgate.			
		<i>oblonga</i>	ditto	Faringdon.			
		<i>truncata</i>	ditto	Folkstone, Hythe.			
		<i>Gibbsiana</i>	marl	Sussex.			
		<i>pisum</i>	gault	Ditto, Yorkshire.			
		<i>striatula</i>	chalk	Norwich.			
		<i>Gervillii</i> , Woodw.	ditto	Norfolk.			
		<i>rigida</i>	ditto	Ditto, Ramsgate.			
		<i>obliqua</i>	ditto	Norwich, Hants		Meudon, Maestricht.	
	(Magas)	<i>pumila</i>	ditto	Norfolk.			
		<i>magna</i> , Woodw.	ditto	Ditto.			
		<i>punctata</i> , Woodw.	chalk	Norwich, Brighton	chalk	Meudon.	
	Crania	<i>Parisiensis</i> , DeFr.	Swaffham	ditto		Normandy, Sweden.	
		<i>striata</i> , DeFr.		ditto		Normandy, Schlenacken.	
		<i>antiqua</i> , DeFr.		ditto		Normandy.	
		<i>stellata</i> , DeFr.		ditto		Sweden, Maestricht.	
		<i>spinulosa</i> , Nils.		ditto		Scania.	
		<i>tuberculata</i> , Nils.		ditto		Schlenacken, in Scania.	
		<i>nummulus</i> , Lam.		ditto		Maestricht, Sweden.	
		<i>nodulosa</i> , Hæn.	green sand.	Sussex; gault, Yorkshire.			
	Orbicula						
	<i>Thecidia hieroglyphica</i> , DeFr.			ditto		Essen.	
	<i>radiata</i> , DeFr.			ditto		Maestricht, Normandy.	
	<i>recurvirostra</i> , DeFr.			ditto		Ditto, ditto.	

Of 100 conchifera belonging to the chalk system, 32 are plagmyonous, 40 mesomyonous, 5 imperfectly known are classed as rudista, and 23 brachiopodous. They are mostly unknown in the strata above or below. The great predominance of mesomyonous bivalves is a

feature common to this and the oolitic system. It must be remarked, however, that it is particularly difficult to settle accurately the number of species of the genera *ostrea*, *exogyra*, and *inoceramus*.

## MOLLUSCA.

Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
Gasteropoda	<i>Dentalium decussatum</i>	gault	Sussex.		
	<i>medium</i>	green sand.	Blackdown.		
	<i>nitens</i> , Hæn.	ditto		chalk	Maestricht
	<i>septangulare</i>	ditto	Belfast.		
	<i>striatum</i> , Mant.		Sussex.		
	<i>ellipticum</i> , Mant.		Ditto.		
	<i>fissura</i> , Hæn.			green sand.	Scania.
	—, Nils.		Ditto.		Sweden.
	<i>Patella locris</i>	ditto	Blackdown.		
	<i>ovalis</i> , Nils.	ditto			Balsberg.
	—, Mant. Lons.		Sussex, Wilts.		
	<i>Pileopsis</i> —, Mant.		Sussex.		
	<i>Helix ? Gentii</i>	ditto	Devizes.		
	<i>Auricula incrassata</i>	chalk	{Sussex; green sand, Blackdown}	ditto	Rouen, Perte du Rhone, Fiz.
	<i>obsoleta</i> , Phil.	gault	Speeton, Yorkshire.		
	<i>turgida</i>			ditto	Scania.
	<i>Melania ?</i> —, Phil.	ditto	Speeton.		
	<i>Ampullaria canaliculata</i> , Mant.	ditto	Sussex.		
	<i>spirata</i> , Hæn.			chalk	Maestricht.
	—, Bt.			green sand.	Montagne de Fiz.
	<i>Planorbis radiatus</i>	green sand.	Haldon.		
	<i>Paludina extensa</i>		Blackdown.		
	<i>Nerita rugosa</i> , Hæn.			chalk	Maestricht.
	<i>Natica canrena</i> Park.	ditto	Parham, Blackdown.		
	Retzii, Nils.				Balsberg.
	—, Lons. Mant.	ditto	Wilts, Sussex.		
	<i>Sigaretus concavus</i> , Hæn.			green sand.	Bochum.
	<i>Delphinula</i> —, Phil.	gault	Speeton.		
	<i>Turbo carinatus</i> , Hæn.			ditto	Coesfeld.
	<i>moniliferus</i>	green sand.	Blackdown.		
	<i>conicus</i>		Ditto.		
	<i>rotundatus</i>		Ditto.		
	<i>pulcherrimus</i> , Bean.	gault	Speeton.		
	<i>sulcatus</i> , Nils.			chalk	Köping.
	<i>Turritella granulata</i>	green sand.	Blackdown.		
	<i>costata</i>		Ditto.		
	<i>duplicata</i> , Hæn.			chalk	Maestricht.
	<i>tebra</i> , Hæn.			green sand.	Weddersleben.
	<i>Pleurotomaria</i> —, Hæn.			chalk	Maestricht.
	<i>Trochus Basteroti</i> , Bt.	chalk	Lewes.	ditto	Paris, Köping.

Geology. Ch. II.	Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.	Geology. Ch. II.
	Gasteropoda	<i>Trochus inaequalis</i> .....	chalk	Sussex.			
		onnatus, Nils. ....			chalk	Köping.	
		gurgitis, Bt. ....	green sand.	Lyme.	green sand.	Perte du Rhone, Fiz.	
		Rhodani, Bt. ....		Southbourn, Lyme	ditto	Ditto, ditto.	
		ciroides, Bt. ....			ditto	Ditto, ditto.	
		linearis, Mant. ....		Sussex.			
		agglutinans? .....		Ditto.	ditto	Aix la Chapelle.	
		lucarinatus .....	ditto	Ditto.			
		reticulatus? .....	gault	Speeton.			
		—, Phil. MS. ..	green sand.	Hythe.			
		<i>Solarium tabulatum</i> , Phil. ....	gault	Speeton.			
		<i>Cirrus depressus</i> Mant. ....	chalk	Sussex.			
		olicatus .....		{ Folkstone, Norlington, Sussex.			
		Sewerbyi, Mant. ....		Hamsey.			
		granulatus .....		Lewes.			
		perspectivus? .....		Ditto, Northfleet.			
		—, Phil. ....	green sand.	Hythe.			
		<i>Cerithium excavatum</i> .....			ditto	Perte du Rhone, Aix la Chapelle.	
		<i>Pyrula planulata</i> , Nils. ....			chalk	Köping.	
		minima, Haen. ....			green sand.	Aix la Chapelle.	
		<i>Murex quadratus</i> .....	ditto	Blackdown			
		calcar .....	ditto	Ditto			
		<i>Rostellaria anserina</i> , Nils. ....			chalk	Köping.	
		Parkinsoni, Mant. ....	ditto	Sussex, Yorkshire	green sand.	Bochum, Coesfeld	
		calcarata .....	ditto	Blackdown.			
		fissura, Lam. ....			ditto	Aix la Chapelle.	
		<i>Pteroceras maximum</i> , Haen. ....				Martiques.	
		<i>Strombus papilionatus</i> , Haen. ....			chalk	Maestricht, Aix la Chapelle.	
		<i>Dolum nodosum</i> .....	chalk	Clayton, Sussex.			
		striatum, Woodw. ....	ditto	Norwich.			
		<i>Eburna</i> —, Bt. ....	ditto	Sussex	green sand.	Perte du Rhone.	
		<i>Voluta ambigua</i> , Mant. ....	ditto	Ditto			
		Lamberti? .....			chalk	Maestricht. (Haen.)	

The numerical predominance of the holostomatous gasteropoda over those which have a notched or canaliculated mouth, is rather less conspicuous in the chalk than in the oolitic rocks; but yet it forms a remarkable contrast with the enumeration of species in the tertiary deposits. Probably all the species are peculiar.

Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
Cephalopoda	<i>Planularia elliptica</i> , Nils. ....				Charlottenbund, Sweden.
	angusta, Nils. ....				Köping, Scania.
	<i>Nodosaria sulcata</i> , Nils. ....			{ chalk and green sand	{ Scania.
	—, Nils. ....			chalk	Ditto.
	<i>Belemnites mucronatus</i> , Schl. ....	chalk.	{ Sussex, Wits. Norfolk, Yorkshire.	ditto	{ Meudon, Maestricht, Poland, Swe- den, Aix la Chapelle, Normandy
	granulatus, DeFr. ....	ditto	Lewes.		
	lanceolatus, Schl. ....	ditto	Hamsey		Quedlinburg.
	Listeri .....	gault	{ Sussex; red chalk, York- shire.		
	attenuatus .....	ditto	Sussex, Folkstone.		
	minimus, Miller .....	ditto	Folkstone.		
	mammillatus, Nils. ....				Ignaberga in Scania.
	scabra, Nils. ....				Scania.
	<i>Baculites anceps</i> , Nils. ....			chalk	Balsberg.*
	obliquatus .....	chalk.	Lewes, Hamsey.	ditto	Scania.
	Faujasi. ....	ditto	Norwich	ditto	Paris, Sweden, Maestricht.
	vertebralis, Lam. ....			ditto	Maestricht, Normandy.
	triangularis, Desin. ....			ditto	Maestricht.
	<i>Hamites armatus</i> .....	ditto	Sussex, Oxon		
	maximus .....	gault	Sussex, Yorkshire.		
	intermedius .....	ditto	Ditto, ditto.	green sand.	Aix la Chapelle.
	tenuis .....	ditto	Sussex.		
	rotundus .....	ditto	Ditto, Yorkshire.	ditto	Perte du Rhone, Aix la Chapelle.
	compressus .....	ditto	Sussex.	ditto	Nice.
	rarecostatus, Phil. ....	ditto	Speeton.		
	Beauvi, Y. and B. ....	ditto	Ditto.		
	Phillipsi, Beauv. ....	ditto	Ditto.		
	spinulosus .....	green sand.	Blackdown.		
	gigas .....	ditto	Hythe.		
	grandis .....	ditto	Kent.		
	plicatilis, Mant. ....	gault	Speeton, Sussex.		
	alternatus, Mant. ....	ditto	Ditto, ditto.		
	ellipticus, Mant. ....	ditto	Sussex	chalk	Normandy.
	attenuatus, Mant. ....	ditto	Ditto, Speeton.		
	funatus, Bt. ....			green sand.	Perte du Rhone, Fiz.
	caneratus, Bt. ....			ditto	Perte du Rhone.
	virgulatus, Bt. ....			ditto	Mont de Fiz.
	cylindricus, DeFr. ....			chalk	Normandy.



Geology. Ch. II.	Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.	Geology. Ch. II.
	Cephalopoda . Hamites	Parkinsoni . . . . .	gault . . . . .	Wilts. Folkestone.			
		gibbosus . . . . .	ditto . . . . .	Ditto.			
		spiniger . . . . .	ditto . . . . .	Ditto.			
		tuberculatus . . . . .	ditto . . . . .	Ditto.			
		turgidus . . . . .	ditto . . . . .	Ditto.			
		nodosus . . . . .	ditto . . . . .	Ditto.			
		baculoides. Mant. . . . .	ditto . . . . .	Ditto.			
		—, Phil. MS. . . . .	ditto . . . . .	Ditto.			
		Scaphites obliquus . . . . .			chalk . . . . .	Rouen; green sand, Mont de Fiz.	
		costatus, Mant. . . . .	chalk . . . . .	Sussex.			
		striatus, Park. . . . .	ditto . . . . .	Ditto . . . . .	ditto . . . . .	Rouen.	
		—, Desn. . . . .			ditto . . . . .	Normandy.	
		Turritites costatus . . . . .	ditto . . . . .	Sussex, Wilts. . . . .	ditto . . . . .	Rouen, Havre.	
		undulatus, Mant. . . . .	ditto . . . . .	Sussex.			
		tuberculatus . . . . .	ditto . . . . .	Ditto.			
		Bergeri, Bt. . . . .			green sand . . . . .	Perte du Rhone, Fiz.	
		Babel . . . . .			ditto . . . . .	Mont de Fiz.	
		— Risso. . . . .			ditto . . . . .	Maritime Alps.	
		obliquus . . . . .	green sand . . . . .	Devizes.			
	Falscheri . . . . .	Ammonites cinctus, Mant. . . . .	chalk . . . . .	Sussex.			
		Deluci, Bt. . . . .				Perte du Rhone, Mont de Fiz.	
	Amalthei . . . . .	Ammonites Stobri, Nils. . . . .			green sand . . . . .	Köpingenolla.	
		Selligunus, Bt. . . . .			chalk . . . . .	Lublin, Poland, Essen; green sand, Fiz.	
		Beudanti, Bt. . . . .			green sand . . . . .	Perte du Rhone.	
		Lamberti ? Sow. . . . .	gault . . . . .	Yorkshire.			
	Macrocephali . . . . .	Nuffieldensis . . . . .	green sand . . . . .	Nuffield, Wilts.			
		Lewesensis, Mant. . . . .	chalk . . . . .	Sussex . . . . .	chalk . . . . .	Essen, Toplitz.	
		peranophus, Mant. . . . .	ditto . . . . .	Ditto			
		nodosoides, Sternb. . . . .				Bohemia.	
		triseulosus, Phil. . . . .	gault . . . . .	Yorkshire.			
		rotula . . . . .	ditto . . . . .	Ditto.			
		venustus, Phil. . . . .	ditto . . . . .	Ditto.			
		concinus, Phil. . . . .	ditto . . . . .	Ditto.			
		marginatus, Phil. . . . .	ditto . . . . .	Ditto.			
	Armati . . . . .	nucleus, Phil. . . . .	ditto . . . . .	Ditto.			
		Rotomagensis, Bt. . . . .	chalk . . . . .	Sussex, Wilts. . . . .	ditto . . . . .	Rouen.	
		Mantelli . . . . .	ditto . . . . .	Sussex . . . . .	ditto . . . . .	Saumur, Bochum, Hanover.	
		tetrammatatus et mo- nile. . . . .	ditto . . . . .	{ Ditto, green sand, Black- down.			
		hippocastanum . . . . .	ditto . . . . .	Lyme.			
		Woolgari, Mant. . . . .	ditto . . . . .	Sussex.			
		rusticus . . . . .	ditto . . . . .	Ditto, Lyme. . . . .	ditto . . . . .	Bochum.	
		rostratus . . . . .	ditto . . . . .	Sussex, Oxfordshire.			
		navicularis, Mant. . . . .	ditto . . . . .	Sussex.			
		clavatus, De Luc. . . . .			green sand . . . . .	Fiz.	
		Gentoni, Deff. . . . .	gault . . . . .	Ditto.	chalk . . . . .	Rouen.	
		hystrix, Phil. . . . .	ditto . . . . .	Yorkshire.			
		catinus, Mant. . . . .	chalk . . . . .	Sussex.			
		catillus, Mant. . . . .	ditto . . . . .	Ditto.			
	Dentati . . . . .	splendens . . . . .	gault . . . . .	Ditto, Kent.			
		virgatus, Goldf. . . . .			green sand . . . . .	Moscow.	
		inflatus . . . . .	green sand . . . . .	Wilts. . . . .	ditto . . . . .	Perte du Rhone, Rouen, Havre, Fiz.	
		lautus, Mant. . . . .	gault . . . . .	Sussex, Kent.			
		auritus, Mant. . . . .	ditto . . . . .	Ditto, ditto.			
		dentatus . . . . .	ditto . . . . .	Ditto, Wilts.			
		canteratus, Bt. . . . .			ditto . . . . .	Buet.	
		? varicosus . . . . .	green sand . . . . .	Blackdown. . . . .	ditto . . . . .	Perte du Rhone.	
		? denarius . . . . .	ditto . . . . .	Ditto.			
		? Goodhalli . . . . .	ditto . . . . .	Ditto, Lyme, Sussex.			
		Bennettii . . . . .	gault . . . . .	Wilts.			
		probosculeus . . . . .	ditto . . . . .	Kent.			
		? planus, Mant. . . . .	ditto . . . . .	Yorkshire, Sussex.			
	Ornati . . . . .	Ammonites varians . . . . .	chalk . . . . .	Sussex, Wilts. . . . .	ditto . . . . .	Fiz, Bochum; chalk, Rouen.	
		conpei, Bt. . . . .			ditto . . . . .	Rouen.	
	Flexuosi . . . . .	falcatus . . . . .	ditto . . . . .	Sussex . . . . .	chalk . . . . .	Ditto.	
		curvatus . . . . .	ditto . . . . .	Ditto.			
		constrictus . . . . .			ditto . . . . .	Lublin, Poland.	

The following species are difficult to arrange under any of Von Buch's tribes.

Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
A. undatus . . . . .	chalk . . . . .	Sussex.		
planulatus . . . . .	green sand . . . . .	Ditto.		
complanatus, Mant. . . . .	chalk . . . . .	Ditto.		
laevigatus . . . . .	gault . . . . .	Ditto.		
parvus ? . . . . .	ditto . . . . .	Speeton.		
curvinodus, Phil. . . . .	ditto . . . . .	Ditto.		
De Luci, Bt. . . . .			green sand . . . . .	Perte du Rhone.
suberistatus, De Luc. . . . .			ditto . . . . .	Ditto.

Geology. Ch. II.	Family.	Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.	Geology. Ch. II.
		<i>A. cristatus</i> .....	gault.	Folkstone.			
		<i>minutus</i> .....	ditto	Ditto.			
	Cephalopoda	<i>Nautilus elegans</i> .....	chalk	Sussex; green sand, Wilts	chalk	Rouen; green sand, Havre.	
		<i>expansus</i> .....	ditto	Sussex.			
		<i>inæqualis</i> .....	gault	Ditto; green sand, Wilts.		Maestricht ?	
		<i>simplex</i> .....	green sand	Blackdown	ditto	Rouen; green sand ? Aix la Chapelle.	
		<i>aperturatus</i> .....	ditto		ditto	Maestricht.	
		<i>undulatus</i> .....	ditto	Ditto	green sand	Bochum.	
		<i>pseudopomgilius</i> , Schl.				Rouen, Perigueux.	
		<i>obscurus</i> , Nils.				Köping.	
		<i>radiatus</i> .....	ditto	Molton, Devon.			
	(Lenticulites)	<i>Comptoni</i> .....	ditto	Wilts	chalk	Scania.	
		<i>cristella</i> .....			ditto	Charlottenbund, Sweden.	
	<i>Lituolites</i>	<i>nautiloidea</i> , Lam.			ditto	Paris.	
		<i>difformis</i> .....			ditto	Ditto.	
	<i>Nummulites</i>	<i>lenticularia</i> , } (Honn.)			ditto	Maestricht; green sand, Aix la Chapelle.	
		<i>Faujasii</i> , (Honn.)			ditto	Maestricht.	
		.....			green sand.	Alps of Savoy, Dauphiné, and Provence, Maritime Alps; chalk, Wimbobla, Saxony, Pyrenees.	

The cephalopoda of the cretaceous system are mostly peculiar to it; and not only minutely, but very obviously, and often generically characteristic of it. Hamites, baculites, scaphites, turritites, the dentated ammonites of Von Buch, are exclusively confined to the gault, green sands, and chalk. It is very remarkable how nearly the whole series of ancient cephalopoda ends with the chalk, and without being represented, ex-

cept in a very small degree, by new forms of the same class, seems to yield place to a vast augmentation of the number of the gasteropodous mollusca, which through all the tertiary system maintain that numerical predominance over the conchifera which is observed in the actual system of Nature. The names in the preceding lists, are chiefly taken from Sowerby's *Mineral Conchology*.

## ANNULOSA.

Name	Rock.	In British Localities.
<i>Vermicularia</i> (Vermetes of authors) }		
<i>polygonalis</i> .....	green sand	Hythe.
<i>concavus</i> .....	ditto	Sussex, Wilts.
<i>umbonata</i> .....	chalk	Sussex.
<i>Sowerbii</i> .....	ditto	Ditto; gault, Speeton.
<i>Serpula</i>		
<i>carinella</i> .....	green sand	Blackdown.
<i>antiquata</i> .....	ditto	Wilts
<i>rustica</i> .....	gault	Folkstone.
<i>articulata</i> .....	ditto	Ditto.
<i>ampullacea</i> .....	chalk	Sussex, Norfolk.
<i>plexus</i> .....	ditto	Sussex.
<i>obtusæ</i> .....	ditto	Parham, Norfolk.
<i>fluctuata</i> .....	ditto	Norwich.
<i>macropus</i> .....	ditto	Norfolk.
<i>spirulæa</i> .....	ditto	Norwich.
<i>granulata</i> .....	ditto	Ditto.
<i>plana</i> , Woodw. ....	ditto	Ditto.

The difficulty of determining species in these variable shells is such, as to throw great doubt over these determinations, made for the most part from single specimens. Objections of the same kind strike us on ex-

amining the twenty-one species of annulosa figured by Goldfuss from the cretaceous strata of Westphalia and Maestricht. The following list contains their names and localities.

Name.	Rock.	In Foreign Localities.
<i>Serpula trachinus</i> , G.		Essen.
<i>lophoda</i> , G.		Ditto.
<i>laevis</i> , G.		Ditto.
<i>triangularis</i> , Mun.		Rinkersde near Munster.
<i>draconocephala</i> , G.		Maestricht.
<i>depressa</i> , G.		Essen.
<i>rotula</i> , G.		Regensburg.
<i>quadricarinata</i> , G.		Ditto.
<i>cincta</i> , G.		Essen, Coesfeld, Aix.
<i>arcuata</i> , Mun.		Regensburg.
<i>subtorquata</i> , Mun.		Near Munster.
<i>sexangularis</i> , Mun.		Ditto.
<i>sexsulcata</i> , Mun.		Amberg.
<i>Noeggerathii</i> , Mun.		Near Munster.
<i>recta</i> , G.		Maestricht.

Name.	Rock.	In Foreign Localities.
<i>Serpula amphibia</i> , G. ....	.....	Maestricht, Bochum.
<i>spirographis</i> , G. ....	.....	Essen.
<i>parvula</i> , G. ....	.....	Ditto.
<i>subrugosa</i> , Mün. ....	.....	Baumberg near Munster.
<i>crenato-striata</i> , Mün. ....	.....	Ditto.
<i>vibicata</i> , Mün. ....	.....	Rinkerode near Munster.

## CRUSTACEA.

Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
<i>Astacus Leachii</i> , Mant. ....	chalk	Sussex.		
<i>ornatus</i> , Phil. ....	gault	Speeton.		
<i>Sussexiensis</i> , Mant. ....	chalk	Sussex.		
<i>longimanus</i> , Sow. ....	green sand.	Lyme.		
— Mant. ....	gault	Sussex.		
— Phil. ....	ditto	Speeton.		
<i>Palinurus</i> —, N. S. Phil. ....	ditto	Ditto, Yorkshire.		
<i>Pagurus Faujasii</i> , Desm. ....	chalk	Sussex.		Maestricht.
<i>Scyllarus Mantelli</i> , Desm. ....	ditto	Ditto.		
<i>Eryon</i> — Mant. ....	ditto	Ditto.		
<i>Arcania</i> — Mant. ....	gault	Ditto.		
<i>Eryæa</i> — Mant. ....	ditto	Ditto.		
<i>Corystes</i> — Mant. ....	ditto	Ditto.		

## CIRRIPEDA.

Name.	Rock.	In British Localities.
<i>Pollicipes sulcatus</i> . ....	chalk	Lewes, Norwich.
<i>maximus</i> .....	ditto.	Northfleet.

## PISCES.

Name.	Rock.	In British Localities.	Rock.	In Foreign Localities.
<i>Squalus</i> , compared to <i>S.</i> } <i>mustelus</i> , Mant. ....	chalk	Sussex.		
— <i>S. galeus</i> , Mant. ....	ditto	Ditto.		
<i>Muraena Lewesiensis</i> , Mant. ....	ditto	Ditto.		
<i>Zeus Lewesiensis</i> .....	ditto	Ditto.		
<i>Salmo</i> ? <i>Lewesiensis</i> , Mant. ....	ditto	Ditto.		
<i>Amia</i> ? <i>Lewesiensis</i> , Mant. ....	ditto	Ditto.		
Fish, parts of. ....	gault	{ Yorkshire, Isle of Wight; chalk Lyme; green sand, Wiltshire, chalk, Wiltshire, Norfolk, Sussex, &c. }	chalk ...	Paris. Bochum. Aix.

## REPTILIA.

Name	Rock.	In British Localities.	Rock.	In Foreign Localities.
<i>Mosasaurus Hoffmanni</i> ....	chalk	Sussex		Maestricht.
<i>Crocodylus</i> , Cuv. ....			chalk	Meudon.
<i>Ichthyosaurus</i> , Phil. ....	gault	Speeton		
<i>Geosaurus</i> .....			green sand.	New Jersey.
<i>Plesiosaurus</i> , (Harlan) ....			ditto.	Ditto.
<i>Saurocephalus lanceiformis</i> , (Harlan) .....			ditto ?	Missouri Territory.
<i>Saurodon Leanus</i> (Harlan) .			ditto ?	New Jersey.
<i>Chelonis</i> .....			ditto.	Maestricht.

## GENERAL SUMMARY.

Plants. ....	22 species, chiefly marine.
Polyparia .....	142 { 52 fibrosa and carnosae, corticifera, 2. 61, cellulifera. 27 lamellifera.
Radiaria .....	95
Conchifera .....	311 { 99 plagymyona. 123 mesomyona. 17 rudista. 72 brachiopoda.
Mollusca .....	206 { 73 gasteropoda. 133 cephalopoda.
Cirripeda .....	2
Annulosa .....	37
Crustacea .....	13
Fishes .....	7
Reptiles .....	8

843 species, almost exclusively marine.

*Tertiary System.*

We have now arrived at the last system of strata deposited in the sea and in lakes; before, as is usually stated, the present races of land animals and plants were called into existence. It is usually stated to be limited as to time between the era of the chalk and the beginning of the modern zoological period; but this definition is something arbitrary in application. As we have seen, on previous occasions, the several systems of strata, however distinct in the great mass, gradually soften into each other at the lines of junction, and sometimes exchange beds, so as to form the whole into a natural and connected series, so it may be with the present set of deposits in relation to the chalk. In England, indeed, as already remarked, this kind of *transition* from the chalk to the tertiaries, is nowhere distinct, nor are we entitled to say decidedly that at any point on the Continent of Europe it is well ascertained.

The blending, however, of tertiary and cretaceous rocks would, if established at many points, occasion no peculiar difficulty in their arrangement, nor alter one just inference drawn from previous observations. It is to be expected from every thing that is known of similar cases, that the great and abrupt change between the chalk and tertiaries in England and in France will be in some other Countries divided into easier gradations, and thus the maxim *natura non facit saltus*, will be found to prevail in this case as in all others.

A greater difficulty however occurs when we attempt to mark the *modern limit* of the tertiary system of strata, arising out of several circumstances important in their history, which scarcely required notice amongst the older deposits.

The ancient systems of strata were almost entirely marine; but

1. The tertiary system includes not only marine, but lacustrine deposits, which sometimes alternate with the marine strata, sometimes appear unconnected with them, and in several instances were evidently altogether independent of them and of each other, being formed separately upon the elevated lands under the influence of the ordinary processes of drainage. Now as similar causes have been in operation long since the tertiary era, and are in operation at present, it is often for this reason very difficult to say what is really the Geological antiquity of a lacustrine deposit, whether it be of the present epoch, or belonging to the tertiary or some intermediate system.

2. Within the tertiary era a variety of land mammalia came into existence which are now extinct, and which it appears had become extinct before what is called the diluvial detritus was scattered, and the elephant and hyæna were destroyed in Northern climes. If instead of antediluvian we should say mastozootic, and instead of tertiary, palæotherian, the generally received inference on this subject is, that the two periods are clearly and distinctly defined. Most of the observations support this view; but in a few cases palæotherian and mastozootic remains occur together, and are supposed to prove that the changes from the earlier to the latter system of organic nature were, like all the preceding, gradually accomplished; that before the palæotheria had become extinct, the ox, mastodon, and rhinoceros had begun to exist.

3. But allowing, for the present, that the palæotherian and mastozootic remains are of different ages, and

agreeing by these characters to separate the diluvial from the tertiary deposits; how are we to apply this distinction drawn from the quadrupedal tenants of the land to the marine strata, in which their remains hardly ever occur? Or if, as in England we find quite easy, we should characterise the diluvial deposits by the mode of their occurrence over all the marine strata, what is to be done with strata like the Sicilian tertiaries, which have perhaps no contemporaneous analogue raised above the sea, and are supposed to show no trace of diluvial currents?

4. The tertiary class is often supposed to include only the deposits which happened before the present system of organic nature was established. But do Geologists really admit what these words imply? We who have used these terms, and have come to reflect on their meaning, answer certainly not, either in theory or in practice. For the *present system of organic nature*, is most certainly recognised in nearly all the marine tertiary strata, if we trust to the evidence which in every other such case has been thought the best: viz. the marine shells. The shells of all the tertiary marine strata are proved by various degrees of evidence to belong to the present *system* of organic nature, for the genera are almost universally the same, though the numerical analogy of the species is very unequal in different deposits.

Neither is it true, that what are called lacustrine tertiaries can in all cases be pronounced to contain exuvie of another system of organic nature; for if this could hardly be asserted of the basin of Paris, what is to be said of Aix and Eningen?

We come now to the terrestrial accumulation, that is to the diluvial and alluvial aggregates, containing bones of quadrupeds in characteristic abundance, and combining with these the notices of similar remains in lacustrine and marine deposits, the causes of past ambiguity, and the hope of future distinctness appear together. It can hardly be doubted that the land accumulations are capable of being classed by the reliquæ of land animals which they contain; and this classification gives us the diluvial era, clearly separate both from the more recent and (if there be any remains of such) the more ancient alluvial periods. But this distinction of the races of land animals into periods, applies only to the land, and the extension of this classification to the productions of the sea can only cause utter confusion, and distrust of the inferences to which more legitimate processes would probably conduct us. In a less degree the same confusion will arise from applying this classification to fresh-water deposits, as the mixture of extinct quadrupeda and recent mollusca at Market Weighton in Yorkshire fully proves.

To be consistent, we must certainly allow that the races of land animals might be altogether changed without any corresponding change of lacustrine or marine shells, and we must limit our classifications to their just application. We must judge of the age and other characters of supracretaceous marine strata by comparison with what is known of the modern condition of the sea; the lacustrine deposits of the same era must be compared to the standard of the modern lakes; and the terrestrial accumulations will derive illustration from comparison with the modern state of the land, and the aqueous agencies upon it. In some instances at present, and it is to be expected that hereafter many more will be established, the relative epochs of certain terrestrial, lacustrine, and marine phenomena may be determined, but it is not the less certain that these phenomena

belong to three independent series, which must be studied apart before they can be understood together.

It must be evident from what has been said before that a considerable proportion of the old strata had at the commencement of the tertiary system been raised above the sea, some parts by violent, others by gentle and continued elevation. In the latter way, we imagine, the chalk and oolites of England to have been a little raised above the sea at this period, so as to leave broad planes of the chalk rising gradually from the sea, and, of course, exposed to the violence of its shores, and other parts dry and fit for the growth of plants and the residence of animals. In France the same effects may be supposed to have happened round the greater part of the basin of Paris, while the old granitic rocks of central France, had sometime before raised themselves to nearly their present altitude, and constituted a shore for the oolites and the chalk. The mountains of Brittany, the chains of the Cevennes, the Jura, and the Vosges were also conspicuous in France, while the Black Forest, Odenwald, Harz, Erzgebirge, and Bohemian mountains generally had assumed their present relative heights. Also all the primary tracts of Britain, Scandinavia, Finland, and the Ural had long since circumscribed the ancient sea, or basin of Europe. But as yet the Pyrenees and Apennines, the Alps and Carpathians, had been only partially raised from the deep sea, though enough it would appear to divide the ocean into limited seas, gulfs, and bays, in which the tertiary strata were to be deposited.

This brief sketch will convey a tolerable notion of the observed extent of the tertiary deposits in Europe. The Eastern and South-Eastern parts of England, a large tract round Paris, another equally large area in the South-West of France, detached deposits in the Loire and the Allier, the valley of the Rhone, the valley of the Rhine from Basle to Mayence; the great hollow between the Jura and the Alps, the plains of the Danube and the Po, the subapennine region, many points in Southern Spain, the central basin of Bohemia, these are the tracts at present best known, but they are not the most extensive. From the Ardennes, Harz, Riesengebirge, Carpathians, and Caucasians, great part of the space North-Eastward to the primary rocks of the Ural and Finland is composed of a variable mass of tertiary rocks resting on secondary and primary formations. The Eastern coasts of North America, large areas in Northern Africa and in the region South of the Himalaya, are covered by tertiary rocks.

As far as appears at present, the marine parts of these deposits were formed beneath waters, some of which were connected with the German Ocean, as the Eastern parts of England, the Northern parts of Germany, &c., others with the English Channel and the Atlantic Ocean, as the South of England, Paris, Bordeaux, and the remainder branched off from the Mediterranean, the Black Sea, the Sea of Azof, the Caspian, &c.

As in the present day the molluscous productions of one sea are distinguishable from those of another, by differing according to latitude and local circumstances, according to the nature of the coasts, influx of rivers, and many other causes, so we may expect the case to have been formerly. This is found to be the fact. The tertiary strata have several common and characteristic features, but they show differences of great importance, both mineralogical and organic, which clearly indicate the difference of circumstances of their production.

We shall first describe the English tertiaries, distinguishing them as marine and lacustrine, and we shall afterwards present a comparative view of the most remarkable contemporaneous foreign deposits.

### *Tertiary System of England.*

The following is a Tabular view of the series of these deposits in England.

	Feet.
Upper marine formation.	Crag, a local marine deposit, consisting of two parts; one a coarse, calcareous, zoophytic, and shelly rock, the other a loose deposit of sand, pebbles, and shells. . . . . 30 or 40
Lacustrine deposits.	Enclosing between them an intervening layer of marine, or marine-lacustrine shells, &c.
Lower marine formation.	Bagshot sand. London clay, with septaria rich in shells. 300 to 600 Plastic clay group, consisting of marl covering the chalk, coloured clays, lignites, pebbles, and sand, with shells.

We must here observe, that in the preceding Table there is probably a hiatus between the London clay and the lacustrine deposits in Hampshire, that there is no case where the crag overlies the fresh-water beds, they being found only in separate districts, and that it is also probable that a hiatus exists between the London clay and the crag. Notwithstanding the want of direct sections, comparisons with the tertiary strata of other districts appear to warrant us in classing the crag as a more recent deposit than the lacustrine beds. This will appear in the sequel.

### *The Lower Marine Formation*

consists of two principal groups which are in many cases very distinctly characterised, and always appear to indicate considerable difference in the state of the waters which produced them.

The *plastic clay* group consists, generally, of green, yellow, and white sands, with or without marine shells, layers of rolled flints, occasionally furnishing attachment to oysters, clays and marls of a yellowish or bluish colour with shells, and sometimes of many various tints, and then mostly devoid of shells. Beds of lignite also occur in the sands of this group.

The Map will show with sufficient accuracy the general range of this group from Essex through Buckinghamshire to Reading and Hungerford, and on the North side of the Kingsclere ridge of chalk, to Guildford and Croydon, and through Kent to Chatham, Canterbury, and Deal. South of the Kingsclere and Wealden ridge it ranges above the chalk from Newhaven, and Brighton by Chichester near to Arundel and Houghton Hill, and thence to Dorchester, including the pipe-clay of Poole Heath, and turning Eastward again forms a narrow ridge of vertical strata between the chalk and London clay of the Isle of Wight.

The sections of the plastic clay group are usually considered to be very irregular and confused, and so, indeed, they are, and mark, upon the whole, a turbulent period and varying velocities of water. But we believe it possible to arrange these varying sections so as to present a tolerably consistent Tabular view thus.

Plastic clay group. Upper part, consisting of coloured sands and coloured clays with beds of lignite, and occasional layers of flints.

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**Plastic clay group.** Middle part consisting of blue clay, or marl, with *cerithia* and other shells, sometimes alternating with sands, with or without shells.

Lower part containing green sands often associated with flints and pebbles, and occasionally full of oyster shells, sharks' teeth, &c.

The following section of Loam Pit Hill, near Lewisham in Kent, by Dr. Buckland, will serve to convey a good notion of the general characters of the plastic clay group near London, except that the quantity of rolled pebbles is smaller than usual.

*London Clay above.*

	Feet.
Alluvium .....	
Striped sand, yellow, fine, and iron-shot .....	10
Striped loam and plastic clay, containing a few pyritical casts of shells, and some thin leaves of carbonaceous matter .....	10
Yellow sand .....	3
Lead-coloured clay containing impressions of leaves .....	2
Brownish clay containing cythereæ, estimated at .....	6
Three thin beds of clay, of which the upper and lower contain cythereæ and the middle oysters .....	3
Loam and sand, in its upper part cream-coloured, and containing nodules of friable marl, in its lower part sandy and iron-shot .....	4
Bed of ferruginous sand containing flint pebbles .....	12
Coarse green sand, containing pebbles .....	5
Ash-coloured sand, slightly micaceous, without pebbles or shells .....	35
Green sand identical with the Reading oyster beds, containing green-coated chalk flints but no organic remains .....	1
Chalk with beds and nodules of black flint	

The green sandy lower part of the group, with or without pebbles, oysters, and other shells, and sharks' teeth, appears to be constant and very characteristic, being found at Sudbury, Reading, Woolwich, &c.; and also occurring in the Isle of Wight.

The blue shelly clays of the middle part are well developed and rich in fossils, (much analogous to those of the London clay,) about Woolwich and other parts of Kent, and attain the monstrous thickness of 200 feet in the Isle of Wight, but they are not so continuous as the green sands. In the New Forest, and at Newhaven, they much resemble the Woolwich beds in their zoological contents.

The upper series of coloured sands, clays, and lignites, arrives at great importance in Hampshire, but is only feebly traceable around London, and appears quite unknown in Essex and Suffolk, and generally on the Northern rise of the chalk from the Vale of the Thames. The pipe clay of Poole in Dorsetshire, which is of white, grey, or blue colour, belongs to this division. It overlies a seam of friable lignite (brown coal) somewhat like Bovey coal.

There are several layers of white pipe clay at Poole Heath, three to five feet each, alternating with black sand, red sand, and brown clay, and covered by white sand. All along the North side of the range of chalk hills which extend from Handfast Point to beyond Corfe Castle, there is an extensive stratum of pipe clay in a horizontal position. It contains a bed of coal exactly resembling that of Alum Bay in the Isle of Wight. (Webster, in *Geology of England*, p. 53.)

The celebrated section of Alum Bay, for which we are indebted to Mr. Webster, exhibits the vertical beds of the plastic clay group of the astonishing thickness of more than 1000 feet.

The series here admits of the same general divisions mentioned above.

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Upper part, consisting of 543 feet of highly coloured and variegated pipe clay, white, yellow, grey, and blackish, and alternating even minutely with beautifully coloured sands. Near the middle are three beds of lignite, in which fruits and vegetable reliquias are observable, and further to the North (nearer the top) are five other beds of the same sort of coal, each a foot thick, under this is a series of coloured and variegated sands 321 feet thick.

Middle part. Dark blue clay 200 feet thick enclosing much green earth, and nodules of a dark argillaceous limestone with shells. (Cytherea, &c.)

Lower part. Green, red, and yellow sand, 60 feet.

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Ch. II.*The London Clay*

is a very simple argillaceous deposit, of considerable Extent and but variable thickness, in one place (Wimbledon) exceeding even 530 feet, and in another (High Beech in Essex) 700 feet. It is usually of a lead-grey, or bluish colour, but dull brown and red clays occur in it, perhaps most usually in the lower part. Green grains are often observable in it, a few sandy layers occur, and these, usually containing green sand, are indurated at Bognor and Selsea into a considerable rock. Septaria abound in it, and some imperfect laminae of marly limestone have been noticed. It lies upon the plastic clay group over considerable tracts in Essex, Berks, Hertfordshire, Middlesex, Hampshire, Surrey, and Kent, on the Northern side of the Wealden ridge, borders the Southern coast from Worthing to Hordwell, and separates the coloured sands and clays of the Isle of Wight from the fresh-water deposits above. It is chiefly interesting for the vast number, beauty, and variety of its organic remains, of which the cliffs at Harwich, Sheppey Isle, Hordwell, Stubbington, &c. are rich repositories. Considerable quantities were also obtained in cutting for the Archway at Highgate.

Having been much exposed to watery action, which it could ill resist, it is often left in insulated hills, upon the substrata of sands and clays. Mineral springs, so common to blue clays, rise in considerable number from the London clay near the metropolis. The most remarkable are those of Epsom, famous for their sulphate of magnesia, Bagnigge Wells, and Acton.

It yields little water to the well-sinker, but on being pierced to the sands below, or, as circumstances may require, to the chalk, great streams of water rush up, and may even overflow the surface if the chalk hills which gather and transmit the water be sufficiently elevated. This is the case about London, under which subterranean streams flow from the chalk of Surrey on one side, and that of Hertfordshire on the other.

The London clay possesses all the characters of a very quiet and continuous deposit, perhaps in deep water, yet not far from shore, since a few considerable remains of land and littoral productions occur in it, as wood, turtles, and crocodiles, but no pebbles nor coarse sands.

The temporary turbulence of the plastic clay period had wholly passed away, and only finer sediment in great quantities found its way to the sea. Shells of the most delicate and fragile forms are perfectly uninjured in this clay, except in the rare case of its being laminated.

*Bagshot Sand.*

We shall place the Bagshot sand described by Mr. Warburton (*Geological Transactions*) above the London clay, on which it rests in the only districts in which

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as yet it has been much noticed. Bagshot Heath and Hampstead are the principal localities. Its fossils are few and imperfect, but are thought by Mr. Warburton to resemble some of those found in the upper marine formation of the Paris basin.

#### Fresh-water Group.

Isle of  
Wight.

For our knowledge of the fresh-water tertiary strata of England, we are indebted to Mr. Webster. They exist only along the Northern side of the Isle of Wight, and on the opposite coast of Hampshire. After the chalk and older strata, together with the plastic clay and sands and the London clay of the Isle of Wight, were thrown by convulsive movements into positions so extraordinary, the fresh-water strata now to be described were deposited horizontally over the line of this great disturbance. What interval of time may have elapsed, or what intermediate Geological phenomena may have occurred between the dislocation of the chalk and marine tertiaries, and the formation of the fresh-water deposits above, cannot be discovered, at least in this situation. It is in the highest degree probable, that very tumultuous deposits must have succeeded the convulsive movements, and it is quite possible that under the fresh-water deposits of Headen Hill others may exist, which, if marine, might render more complete than it is the English series of marine tertiaries.

The fresh-water strata of the Isle of Wight are parted into two minor groups by an intermediate set of layers of light green marl, 36 feet in thickness, containing in extraordinary abundance and great perfection marine shells of the genera *potamidum*, *voluta*, *fusus*, *natica*, *ancilla*, *cyclas*, *venus*, *cytherea*, *ostrea*, &c. These are distinct from the fossils of the London clay. Some species in this bed are decidedly fresh-water mollusca, as *neritina-like fluviatilis*, and *melanopsis*. *Potamida*, which are numerous, appear to indicate an estuary deposit; and it is probable that we may be justified in regarding the whole of this, which is called the upper marine of the Isle of Wight, as a local estuary deposit, caused by some temporary physical change in the region between the eras of the two decidedly lacustrine groups, which it separates.

#### Crag.

Range and  
characters.

The most recent of all the marine stratified deposits is also one of the most irregular. It occurs only in the Eastern part of England over a narrow space of little elevation from the cliffs of Walton in Essex to beyond Aldborough in Suffolk. It is also known to some extent in Norfolk, particularly at Bramerton near Norwich.

In this short course the crag is found to rest on the London clay at Walton and Bawdsey, and on chalk at Bramerton, being evidently a much later deposit than either and wholly independent of them. It exhibits also considerable variation of character. Its general aspect in numerous pits in Suffolk is a ferruginous mass of shells, dark pebbles, and bones and teeth of fishes and reptiles, mixed up in a confused mass of sand, sometimes grouped into beds, and sometimes exhibiting oblique and disordered laminae, very much resembling the general character of a modern very shelly beach. And from the manner in which it lies in the country about Ipswich and at Bramerton, there

can be little doubt that it is really an ancient beach of the German Ocean. But about Aldborough and Orford the crag assumes a totally different character, becoming, in fact, a zoophytic limestone, an accretionary rock, formed by the cementation of coralline reliques, shells, and calcareous sand, probably after the manner of the Guadeloupe accretionary limestone, and a similar littoral formation on the coast of the Isle of Ascension. This coralline limestone contains some of the most characteristic shells of the ordinary crag, and is clearly of the same era as that heterogeneous deposit.

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The quantity of shells contained in the ordinary Shells of the Crag. pebbly crag of Suffolk is beyond all calculation. The name of crag is, we believe, derived from a British word signifying shell, and the Suffolk pits have been for a long time in work solely to manure the ground with their calcareous exuviae. The number of species here buried is also very great. Upon comparing them with recent kinds we are presented with very curious and striking results. There are several of the crag shells so exceedingly similar to recent shells of the German Ocean, that it is impossible to distinguish them. *Turbo littoreus* retains its colour, many others are with difficulty separated by minute discrimination; but some, as the corals of Orford, *pecten princeps*, *terebratula Dalei*, and others, are evidently unlike any thing now existing in the German Ocean, and indeed not now to be paralleled in any part of the World. A small number of the crag shells appear very similar to some in the London clay, but in general they have few common analogies, and the most cursory observer must be struck by the total difference of general aspect. The London clay shells recall to our memory the shores of a *Tropical climate*, the crag fossils speak to us of an ancient race of shells of *our own seas*. But the corals are *sui generis*, and upon the whole, those Geologists who are most desirous of uniting the crag deposit to the present system of Nature, must acknowledge that it bears the stamp of an ancient and peculiar era. It has often been stated, that bones of elephant, teeth of mastodon, &c. have been found in the crag. This mistake, as we believe it to be, may have arisen partly from the notion once prevalent, that crag was only a particular kind of diluvial deposit, and partly from attempting to supply an omission in Mr. Smith's Work, (*Strata identified*), in which the tooth of a mastodon is figured from a noble specimen now, with this original collection, deposited in the British Museum, but without mention of locality. It was picked up under the diluvial cliff at Happisburgh, from which so many elephantoid teeth and bones have fallen into the sea. A very unexpected addition to the list of organic remains of the crag, is the badger, (probably undistinguishable from the common European species,) of which good specimens of the skull and leg bones are in the Yorkshire Museum.

It must evidently be of little use to give sections of such a deposit as the ordinary crag. We shall therefore subjoin only Mr. R. Taylor's account of the Bramerton pit, and mention that, in general its thickness is about 80 feet, and its greatest height above the sea, in Walton Naze, 50 or 60 feet.

	Feet.
1. Sand without organic remains.....	5
2. Gravel .....	1
3. Loamy earth .....	4
4. Red ferruginous sand, containing occasionally hollow ochreous nodules .....	1½
5. Coarse white sand, with a vast number of crag shells..	1½

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6. Gravel with fragments of shells.....	14
7. Brown sand, in which is a seam of minute fragments of shells 6 inches thick .....	15
8. Coarse white sand with <i>crag shells</i> , similar to No. 5. tellins and murices most abundant .....	34
9. Red sand, without organic remains .....	15
10. Loamy earth, with large stones and <i>crag shells</i> .....	1
Total.....	49
Large irregular black flints crowded together <i>in situ</i> in the chalk. Attached to these flints are echini, terebratulae, indocerami, and belemnites .....	1
Chalk to the bed of the river .....	15

*Foreign Tertiary System.*Under what  
circum-  
stances de-  
posited.

The disturbances which preceded the deposit of the whole or the greater part of the tertiary strata, were very extensive, and appear to have operated considerable changes in the configuration of the land, and to have left the European seas, certainly expanded much beyond their present limits, but yet pretty evidently related to the present depths of the Atlantic, Baltic, and Mediterranean. It has long been the custom to speak of tertiary strata as being particularly deposited in *basins*; an inaccurate use of this term, for the tertiary strata are not more, nor perhaps so much, separated into basins as many of the older strata. We recognise, indeed, in them a greater local diversity, such as at present obtains, both with respect to the materials deposited and the organic remains entombed, in separate branches of the same sea, or at distant and dissimilar parts of the same coast. The true way of considering the tertiary strata is, to view them as the varied deposits of one long period, produced chiefly in branches of one great ocean, variously divided by the elevated lands. Some particular deposits may perhaps be best explained by allowing the existence of mediterranean seas, or even salt-water lakes. Cases in which fresh-water, and marine shells alternate must be examined upon their own evidence, to learn whether such alternations were produced in a lake, or at an estuary; and finally, the true fresh-water strata of the tertiary period must be separately treated, having such relations to the marine tertiary accumulations as the fresh-water formations of the present day have to the deposits now in progress below the sea. Thus we shall have purely marine strata, marino-fluvial, or marino-lacustrine strata, and lacustrine strata, all referable to the tertiary period, the relative eras of which can sometimes be correctly determined, sometimes satisfactorily inferred, and in other cases only conjectured.

The relative age of strata which were deposited in the same branch of the sea, can be determined by observation, even though subsequent convulsions may since have separated the deposit into detached portions, as for instance the Hampshire and the London marine tertiaries. It can be inferred satisfactorily, even for originally distant deposits, when large suites of organic remains, not differing more than we may expect to happen in such cases, concur with a general analogy of Geological position; and in this case, the inference is the stronger, if the data analyzed and referred in portions to successive periods, apply in a similar manner to the two localities.

The mineralogical character of the deposits is of importance in proportion as the deposits happened in the same branch of the sea, along the same line of coast, parallel to the same range of mountains, or to similar ranges of analogous rocks. In short, tertiary strata may

be expected to show close agreement, considerable resemblance or general analogy, according to the local circumstances of their production, and it is perfectly consistent with Geological experience and sound theory, that the clay of London, the calcareous gravel of Paris, and the lower subapennine marls, may be exactly contemporaneous deposits, deriving their peculiar character from the peculiar circumstances of their localities. If we do not so often find in the older systems of strata these great mineralogical contrasts between exactly contemporaneous strata, we must remember that the circumstances of land and sea, when the earlier deposits happened, were more uniform, and that by a long succession of convulsions the tertiary sea was made to flow round islands and promontories, containing a vast variety of rocks, reared in deep or shallow waters, and exposed in various degrees to the processes of disintegration.

We may venture by the aid of what is known of the effect of former convulsions, and the help of the characters furnished by the newer strata, to describe the hydrography of the great European Sea in which tertiary strata were accumulated.

It may perhaps be described as an immense inland sea, bounded on the West by a broken line of elevated land in Spain, Auvergne, Brittany, England, Scotland; on the North by the Scandinavian peninsula, Finland; on the East by part of Russia, the Ural, the mountain circle which encloses the Aral, the Caspian and the Black Sea, and a line prolonged through Syria toward the Red Sea; on the South by a line including the present Mediterranean, part of the Libyan Sands, and Egypt. This ancient Mediterranean appears to have been connected with the Bay of Biscay and the Atlantic by shallow channels between Angers and Poitiers, and by the line of the Canal of Languedoc. It embraced the North Sea, and so probably communicated with the Northern Ocean, included a part of the Baltic, and was open to the Indian Ocean through the Red Sea.

In this vast area rose at that time irregular tracts of land, forming upon the whole two islands. The Northern island, stretching in a sweep from the Cevennes to the Carpathians, and including the great plateau of central France, the Jura, Vosges, Schwartzwald, Ardennes, Tannus, Westerwald, Teutoburger Wald, Harz, Erzgebirge, the circle of Bohemian and Moravian mountains, and the long range of the Carpathians. In the Southern island, rose in partial peaks, and with small surface, the Alps of that epoch, connecting themselves with the Apennines and the mountains of Dalmatia, Croatia, and Greece. The ancient Sea of Bohemia and the Sea of the Rheinland were entirely or nearly surrounded by land; the Seas of Switzerland and Hungary expanded into the Black Sea, and contracted their waters into a narrow channel along the line of the Rhone, there to unite with the Mediterranean; and the basin of Paris appears to have been only partially connected by shallow channels with the North Sea or the Bay of Biscay.

Viewed then in connection with existing Seas, we may consider the inland tertiary Sea in several portions.

1. The arms and branches of the Mediterranean, stretching up the extended Gulf of Lyons, the Sea of Switzerland and Hungary and the extended Adriatic Gulf, washing the Eastern part of Spain, Libya, and Egypt, and joining the Red Sea.
2. The dependencies of the Atlantic and North Sea, as the Hordaux basin which was also connected with the Mediterranean, the basin of Paris, the great Sea of England, and the Netherlands. To these may be joined the arch of Northern Germany, Russia, and the Countries bordering on the Black

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rope, &c.Its relation  
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Sea and the Caspian. We might perhaps be justified in making a separate division for the latter surfaces, could we appeal to any satisfactory account of the organic reliquæ of countries which as yet are very imperfectly known.

For comparison with the English series, we shall first take the example afforded by the basin of Paris, so admirably described by Brongniart and Cuvier, and on that account frequently appealed to as the general type of tertiary formations.

Following the general classification of Messrs. Brongniart and Cuvier, we shall divide the Parisian marine-lacustrine strata into five groups, in the order of their eras.

5. Upper fresh-water or epilimnic group.
4. Upper marine (sands and marls.)
3. Lower fresh-water or palæotherian group.
2. Lower marine (calcaire grossier.)
1. Plastic clay group, lately subdivided by M. Brongniart into three groups. (*Tableau des Terrains.*)

Plastic clay group.

Our remarks on these deposits will be as concise as the great interest attached to a right understanding of the mode of their formation will allow. The idea we formed to ourselves from a consideration of the plastic clay group of England, was that of a varied series of deposits, consequent upon some considerable convulsions, partly derived from the waste of the cretaceous system, and accumulated in a sort of estuary of that system. Pebbles and sands, with or without shells in confusion, a few bands of clay with shells, and beds of lignite, layers of pipe clay, and plastic clay, lying in sand, compose the rather heterogeneous group, which ends upwards with the abundant tranquil deposit of London clay.

On the great scale, the plastic clay group of the basin of Paris presents very analogous characters. It rests on the irregular and worn surface of the chalk, contains accumulations of pebbles, beds of lignite, layers of coloured plastic clay, and by occasionally including beds of calcaire grossier, analogous to the shelly layers of the English group, appears to leave hardly any important point of resemblance unsatisfied. On a careful review, however, some differences arise. The order of succession of the several parts is not exactly similar. The French series taken generally may be thus expressed.

Upper part consisting of potter's clay, marls, sands, and much lignite, the clay containing many lacustrine shells, as cyrenæ and melanopides, alternating with a few marine shells, as ostrea and cerithia; the lignites containing remains of mammalia and fresh-water reptiles.

Middle part or plastic clay and sands, sometimes alternating, the former generally beneath, of very uncertain thickness, indistinctly stratified and devoid of shells.

Lower part very local, consisting of fragments of chalk, flints, &c.

These deposits are very unequally spread in the basin of Paris, and the lignite with shelly clays and marls belongs principally to the vicinity of Soissons. We may draw the following inferences. (1.) That the convulsive movements which wasted the chalk of England, and raised its originally deep strata to a littoral and estuary situation, were also experienced in the basin of Paris. (2.) That in this estuary irregular deposits happened, both marine and fresh water, the latter prevailing in particular places more than in the corresponding basins of England, and recognised by distinct layers of fluviatile mollusca, sometimes alternating with deposits containing a few marine shells. The basin of Paris seems therefore to have been at first an estuary, admitting into it considerable currents of fresh water from rivers or lakes,

containing shells, crocodiles, and turtles, and transporting vegetables; but the deposits were generally more tranquil than the contemporaneous products of England.

The "lower marine" group, or calcaire grossier, and its coeval and associated sandstones, form the principal and characteristic rock of the Paris basin, in which the vast number of marine shells occur. The calcaire grossier is a granular, sedimentary, sandy, yellowish-white limestone, of considerable thickness, regularly bedded and jointed, with partings of a marly nature, including occasional beds of sand, and in some cases lignite and marls. The lowest part of the rock is usually filled with green silicate of iron, and can hardly be distinguished from some kinds of marly green sand. It contains hardly the least trace of metallic substances, but encloses a few beds of hornstone, some cubic fluor, quartz, and calcareous spar. It is the building stone of Paris. In some parts, it is replaced by a development of sandy beds, which often exhibit glistening fractures. Pebbles lie in it, chiefly at the top and the bottom. Upwards of 1500 species of marine shells belong to this group, and only a very few land or fresh-water species, rarely brought down with vegetables, diversify the character of the deposit. A great proportion of the shells of the London clay are recognised among the more numerous reliquæ of the Paris basin.

The lignite and marls occasionally included near the top of the calcaire grossier, (Brongniart,) remind us that the action of the fresh waters, though nearly unobserved during this long period of the deposition of the calcaire grossier in quiet sea, might easily be recalled to the basin of Paris by a change of local circumstances.

Such a change occurring, a part of the basin of Paris was surrendered for a time to the undisputed possession of fresh water, and the following group was deposited.

The palæotherian, or lower fresh-water group, is principally, says M. Brongniart, a chemical deposit from water, or at least this mode of origin is very frequently to be traced in it. Coarse mechanical aggregates, the result of violent currents, are unknown in it; while gypsum, silicious nodules, and agates are frequent, and sulphate of strontia, carbonate of lime, and silicate of magnesia occur in the marls which compose a large part of the mass of the formation. But it is from the remains of terrestrial and fresh-water plants, and the exuvæ of land and fresh-water animals, that this group of strata receives its most exact as well as most interesting characters. In the interior of its mass no marine bodies of any kind have been found, but several plants and shells of the land and fresh water, generically identical with existing tribes, as well as land quadrupeds belonging to genera now extinct. The study of these quadrupeds, first awakened in Cuvier that indefatigable zeal in the examination of fossil animals, which has established the permanent union of the highest branches of Geology and Zoology.

Argillaceous and calcareous marls with limonæ, frequently alternating in very thin laminæ, (a common character of lacustrine deposits of all ages,) constitute the mass of this palæotherian group; gypsum in broad crystallized masses, of a vertically prismatic structure,\*

\* M<sup>r</sup> Chantrey, whose unrivalled eminence in his profession is united with very extensive and accurate information on other subjects, has observed in the interior of plaster casts of large statues, which had been subjected to a drying heat of 350°, an irregularly prismatic structure, comparable to that of the gypsum of Montmartre.

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not stratified, is frequently associated with them, as in the basin of Paris, at Pay en Velay, and at Aix en Provence, silicious limestone locally diversifies them, and yields agates, menilites, nectic quartz, &c. To this group M. Brongniart also refers the lignites which lie in the molasse of Switzerland. The quadrupedal reliques are, perhaps exclusively, found in the gypsum, and few other organic bodies accompany them.

This evidently fresh-water group occurs in many parts of France, sometimes, as in Auvergne and Cantal, without the least trace of a genuine marine tertiary basis. About Montpellier it is found in combination with marine deposits nearly as in the Paris basin, and there appears good reason to believe that the causes which repelled the sea from that basin were extensively at work in other parts of Europe. This indeed is not a very difficult part of the problem. The expulsion of the sea may easily be imagined to have happened by the elevation of new land, or by a great local dislocation, such as we know to have often occurred, and thus a fresh-water deposit in the basin of Paris might be laid on a basis of immediately antecedent marine tertiary strata, at the same epoch that in other parts of France elevated above the sea before the tertiary period, these deposits were laid on any of the older rocks. From the estuary or lake which we now call the basin of Paris, to the mountains of Auvergne, there might be formed, contemporaneously, (that is, in a given Geological period,) many fresh-water deposits of varying character, under varying conditions, which are to be ascertained by special investigation of each case. But after the completion of this lower fresh-water deposit, subterranean movements brought back the sea into the basins of Paris and Montpellier, at the same time that marine exuvia were introduced into the basin of Hampshire. It does not follow, as a necessary inference from the data before us, that this subterranean movement was centred below the basins of Paris, Montpellier, and Hampshire, nor that these basins were raised or lowered at all; it is only certain that subterranean movements must have occurred in such a manner as to interrupt and restore at intervals the connection of these districts with the ancient sea. In what respect is this different from the case of the Weald of Sussex and the ancient coal basin of Yorkshire?

Upper marine group.

The "upper marine" group, produced in the basin of Paris by the marine irruption which covered the palæotherian gypseous marls, is composed chiefly of sands of many colours, occasionally indurated to stone, with fewer shells than in the lower marine group. The base of the group is, at Montmartre, a mass of calcareo-argillaceous marls, greatly analogous to those of the fresh-water group below, a gradation of character very much to be expected; conglomerates lie on the coloured sands in the Northern and Eastern parts of the Paris basin. A sandy, shelly limestone containing bones of the palæotherian, and also of the subsequent diluvian era, called *calcaire moellon* by M. de Serres, abounds at Montpellier and Narbonne. The molasse of Switzerland, a very complex and disturbed deposit, is referred to this era.

Upper fresh-water group.  
(Epilimnic) group.

The parallel between the three basins of Hampshire, Paris, and the South of France, is drawn still closer by the occurrence in all three of "upper fresh-water" beds, the last usually included in the tertiary strata. It must in some cases be doubtful whether the upper fresh-water deposit recognised in a tertiary district be of the antiquity of this Parisian epilimnic group, and it

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is highly probable that lacustrine deposits will be found of all intermediate ages from the date of the uppermost tertiaries of the Paris basin to the deposits of the modern era. Such, perhaps, are the lacustrine groups of Eningen and Georgesgemund, which have become better known to the English reader in consequence of Mr. Murchison's descriptions. But, in the case of the localities mentioned above, this doubt is not to be entertained. The most characteristic rock of this group in the basin of Paris is the millstone, a silicious rock full of cells and tubular sinuosities, attributed to the extrication of gas from the bed of the lake, as is known to happen in ordinary cases, and some fresh-water shells and seeds of chara. (Gyrogonites.) In other districts, especially in Italy, a marly limestone, analogous to the travertine which is daily formed there by carbonated springs, is considered by Brongniart the representative of this group, but it is obvious that this tufaceous deposit may be of all ages. The upper fresh-water deposit, with, probably, other recent deposits of the same nature, is recognised in Auvergne and Cantal, on the Loire, Allier, and Cler, in the Department of Gard, in Switzerland, Austria, and Hungary.

To these characters of the strata in the Paris basin, Faluns of described by MM. Brongniart and Cuvier, must be added a notice of a set of gravelly sands in the Faluns of Touraine, long celebrated for abundance of shells and other organic remains, but which were first examined with attention by M. J. Desnoyers. Along the line of the Loire valley at several points, as well as at Rennes, shelly and gravelly deposits occur, which, from Desnoyers's investigation, appear certainly to be of posterior date to the whole Parisian formation, and to contain not only a variety of shells and corals distinct for the most part from those of the Parisian tertiaries, but also a mixture of quadrupedal remains, both of the palæotherian and mastozootic era. Besides palæotherium, lophiodon, and a species of anthracotherium, which would generally be referred to the era of lacustrine tertiaries, there are bones of mastodon, hippopotamus, rhinoceros, tapir, horse, and deer. These, the most recent, probably, of all the deposits connected with the Parisian series, are compared by M. Desnoyers with the English crag; but the propriety of this reference is denied by Mr. Lyell, on the ground that their suites of organic remains have not the same ratio of analogy to existing tribes; the resemblance of the deposits is, however, remarkable. Thus a sequence of tertiary deposits of the same general characters appears to be clearly ascertained in the Southern parts of England and the Northern parts of France, and the beds in the two localities are of the same, or nearly the same age. This series has three principal marine terms, of which the lower one (London clay in England, calcaire grossier in France) is very continuous, and the most important, the middle one is variable, and the upper one local and littoral, perhaps, we may add, of rather uncertain date. The series contains also two lacustrine terms, and one, the lowest of all, a product of transient convulsions consequent on the rise of the chalk strata.

This agreement is very interesting. Yet it is not to be thought that in other parts of Europe, which are not subjected to the same repeated convulsions, a similar sequence of marine with similar interpolations of lacustrine deposits should often be met with. On the contrary, it ought to be expected that when the tertiary deposits are wholly marine, the triple character, which

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in France and England they derive from definite periods of convulsion, should be confounded into a general series of many graduated or alternating terms, as happens to the oolitic and other extended marine systems. The further descriptions of tertiary strata, introduced for comparison with those of England, will be divided into marine and lacustrine; the former will be first noticed.

South of  
France.

The tertiary strata of the South of France are generally coeval with those of Paris, and the greatest assemblage of shells and other marine remains lies in sandy and subcalcareous beds, thought by M. Brongniart to be of the same age as the interlacustrine sands of Paris. In the districts of Bourdeaux and Dax, 600 species of shells have been collected from these strata, which Mr. Lyell (vol. iii) arranges in four divisions thus:—

4. Silicious sand without shells.

5. Gravel.

2. Sand and marl with shells.

1. Blue marl with shells, sometimes 200 feet thick.

Below all these calcareous strata occur with shells of the Paris basin.

M. de Serres has shown the much greater accordance which the Bourdeaux and Montpellier shells bear to those of the subapennine formation of Italy than to the strata of the basin of Paris, and it is from comparison of the organic remains that Mr. Lyell ranks together the Bourdeaux and Touraine shells, and puts them above all the Parisian beds. It is desirable to attain an accordance of opinion in the relative age of these strata, because they furnish common ground of comparison for the deposits which border the Apennines, the Alps, and the Carpathians.

North of  
the Alps.

The most complete section of tertiary strata along the Alps has been furnished by the researches of Murchison and Sedgwick in Lower Styria.

Uppermost group,  
calcareo-arenaceous.

Calcareous sands and pebble beds, calcareous grits and oolitic limestones, containing many shells, some of these of existing species.

Middle group,  
calcareous.

White and blue marl, calcareous grit, white marlstone, and concretionary white limestone with shells.

Below this is a coralline limestone, with shells, in one place 400 feet thick, associated with marls.

Lowest group  
observed.

Conglomerate with micaceous calcareous sand, and millstone conglomerate. Blue marly shale and sand, with shells analogous to those of the calcaire grossier and London clay.

Shale and sandstone with beds of lignite, accompanied by fluviatile and terrestrial exuviae.

Conglomerates, grits, and micaceous sandstones.

The coralline limestone here mentioned serves as a good line to connect the sections along the line of the Carpathians. At Vienna, Murchison and Sedgwick give the following series:—

Alluvial beds? of loess and gravel, the latter containing bones of mastodon, tapir, anthracotherium, &c.

Fresh-water limestone.

Leithakalk or coralline limestone and calcareous conglomerate.

Upper blue marls and sands, very rich in shells, yellow sand and shells.

Lower group Lower blue marls 300 feet, compared to London clay.

Transylva-  
nia, &c.

In Transylvania, Boué gives the series thus:—

Upper group shelly sands, marine and fresh water.

Sandy coarse limestone, equivalent of the Leithakalk.

Molasse.

Clay and marls blue and yellow.

And this applies to Moravia and the West of Hungary, where the lower beds are inclined toward the Carpathians.

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Below all these tertiary strata, in Geological position, but raised to a great height in the Alpine region by powerful dislocations, occur those shelly marls and sands with conglomerates and traces of lignite, which have acquired celebrity from the researches of Murchison, Sedgwick, Boué, Von Lilienbach, and other Geologists. The discussions on their relative age are yet unsettled, because no sections can be obtained, under the difficult circumstances of the case, which put in a clear order of uninterrupted succession the whole mass of tertiaries, or allow a very confident deduction concerning the relation of all the parts taken separately. The obscurity of the subject is increased by the admitted indistinctness and variation of mineralogical character in the tertiary sands and conglomerates of the plains of the Danube. Yet it is not to be supposed that no inferences can be grounded on the laborious investigations of the eminent Geologists above named. The Gosau shelly beds are limited below by the Alpine limestone at Gosau, and in the Rentersberg by the same limestone, (hippuritic,) covered by grey or reddish marls and marlstone containing a few fossils of the chalk formation: above, these beds are known to pass under the molasses of the plains North of the Alps. Two sections, derived from the labours of Murchison and Sedgwick, will, with this understanding, sufficiently show the nature of the beds. The first is across the Valley of Gosau.

Uppermost group. Red and green slaty micaceous sandstone several hundred feet thick. (Cap of the Horn.)

Second group .... Green micaceous gritty sandstone, extensively quarried as whetstone, succeeded by yellowish sandy marls. (In the Ressenberg.)

Third group .... Vast shelly series of blue marls, alternating with compact limestone and calcareous grit; traces of vegetables above, abundance of shells and corals in the middle and lower part. (In the Valley of Gosau.)

Lowest group .... The above series gradually changes to beds of a more conglomerate character, which pass into red sandstone and marl containing gypsum; a coarse conglomerate, forming the base of the whole system, rests upon and abuts against the Alpine limestone. (Rusebach.)

The discontinuity between the lowest part of this section and the top of the Alpine limestone is partially remedied in the Untersberg, where a series of four terms likewise appears.

Uppermost group. A great succession of alternating masses of bluish micaceous marl, slate, clay, sandstone, and conglomerate. Some of these marls contain beds of gypsum and fossils resembling the suite of Gosau.

Second group .... Beds of blue micaceous slate clay, and greenish micaceous sandstone.

Third group .... Sandy micaceous marls, alternating with conglomerates, and micaceous calc grit with nummulites. Subordinate to this system are red and variegated marls with gypsum.

Lowest group .... A great deposit of marl and marlstone, generally of a grey but in some places of a red colour; containing a few fossils resembling those of the chalk formation.

These beds are conformed in declination to the Alpine limestones of the Untersberg.

The question lately discussed respects the age of these Gosau beds. Messrs. Murchison and Sedgwick conceive them to be the lowest of the tertiary series of the Country, and to have so much analogy to the system

Age of the  
Gosau beds

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below as to be properly regarded as one of the connecting links of the cretaceous and tertiary rocks. M. Boué ranks them with the green sand system. On appealing to the organic remains, we learn that the affinity of genera, and the proportion of univalves and bivalves, bring the Gosau beds to a tertiary type; an examination of the species leads M. Deshayes to declare, (Lyell, vol. iii. p. 327.) that none of the Gosau shells are found in any recognised tertiary stratum, but that some of the most characteristic species of Gosau occur in the green sand below the chalk at Mons in Belgium. His researches have led him besides to the following decisive general statement, that no shell has yet been found which is common both to tertiary and secondary strata! Our own impression on the subject, derived from comparing the statements of those eminent writers who have enjoyed the fullest advantages of original examination, can be of no importance on either side; it will be more useful to set an example, unfortunately rare in such discussions, of deliberate indecision, and to appeal to future discoveries. Two remarks, however, must not be omitted. Though all the instances upon record should be found strictly to agree, (even when modified by further discoveries,) with that valuable and practical conclusion for which Geology is indebted to Deshayes, yet this conclusion is general, not universal, and cannot be employed to predicate the result of any new investigations. And again, though certain genera may not yet have been recognised among secondary strata, the deduction of the age of the Gosau beds from this source is of the same conditional character.

tertiary

The primary and secondary Swiss mountains are bordered on the North by a vast thickness of conglomerates, sands, calciferous grits, and lignites with mammiferous quadrupeds. These are referred by Brongniart to the interlacustrine marine beds of Paris, but the shells as yet found in it are few. M. Studer, of Berne, has amply described this immense and disturbed deposit.

subapennine deposits

The subapennine strata are all that remain to be noticed in these comparative sections. No one since Brocchi has been more successful in the examination of these strata than Mr. Lyell, and they furnish much of the evidence which supports his classification of the tertiary system into eocene, miocene, and pleiocene formations according to the degree of analogy which the organic fossils of those groups bear to existing races of marine animals. They are of enormous thickness, (several thousand feet,) and must have required very long periods for their accumulation in the Mediterranean, from which they have been uplifted to considerable elevations on each side of the secondary Apennine ridges. The mass consists of innumerable alternations of calcareous and argillaceous marl, light brown, or blue, but the variation of mineral character is slight through the whole series, and not at all sufficient to furnish permanent marks of separation into groups. It is altogether like the sediment which we may suppose to be quietly deposited on the bed of the Mediterranean, by rivers which have left their coarser detritus inland. Beds of lignite are sometimes interstratified, as at Medesano near Parma; subordinate beds of gypsum interstratified with shelly marls and sand also occur in the Parmesan. Sandstone is also interstratified, and rarely compact limestone replaces a

portion of the calcareous marls. The whole is covered in places, and unequally, by a coarse yellow sand and conglomerate, in which alternations of fluviatile and marine exuvies are traceable, and other circumstances are observed which mark estuary or littoral action.

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This may be taken as the character of the middle subapennine formation. The tertiary strata in the hill called the Superga, in Piedmont, have been described by M. Brongniart and other writers, and from personal examination with Mr. Murchison, Mr. Lyell has inferred that they are the oldest part of the tertiary system in Italy. Fine green sand and marl, and a subjacent conglomerate, (the boulders being of primary rocks,) compose these strata, which dip at the extreme angle of 70°, under the more horizontal bluish subapennine marls of the plains of the Tanaro.

The most recent portion of the subapennine deposits is exemplified by Mr. Lyell in the tufaceous formations of Naples, the calcareous strata of Otranto, and probably the greater part of the tertiary beds of Calabria. But the most satisfactory view of the newest tertiary strata, is obtained in the Val di Noto, Sicily. Since Dr. Daubeny's account of that island, the phenomena of its stratified rocks have excited much attention, and Mr. Lyell has been eminently successful in deriving from them important inferences concerning the relative ages and periods of elevation of submarine strata. The following is an abstract of his descriptions.

The whole series of strata in the Val di Noto is divisible into three principal groups.

The uppermost group consists of limestone, sometimes 700 or 800 feet thick, often corresponding in mineral character with the calcaire grossier of Paris, but often more compact. It is regularly stratified and cavernous. These characters, however, are liable to vary in different parts of the island; near Noto it has the concretionary spheroidal structure of the form of the Italian travertino, and contains terrestrial vegetables. These strata prevail not only in the Val di Noto, but, as Dr. Daubeny stated, cap the hill of Castrogiovanni, 3000 feet above the strata. The organic remains of this limestone (generally casts) belong, with hardly any exception, to existing species.

The middle group, not abruptly distinguished from the upper one, consists of white calcareous sand, sometimes with a tendency to oolitic and pisolitic texture, such as the travertino of Tivoli; at Floridia near Syracuse, it changes to conglomerate with calcareous pebbles, associated with sandy limestone full of broken shells. In some parts of Sicily, this group seems to be represented by yellow sand, exactly resembling that superimposed in the blue subapennine marls of Italy.

The lowest of the three groups consists of an argillaceous deposit of variable thickness, called *creta* in Sicily. It resembles the blue marl of the subapennines, and encloses shells and corals in a beautiful state of preservation. The shells belong, with few exceptions, to recent species.

Other marly strata, probably tertiary, occur below, with gypsum, sulphur, and salt.

#### Relative Antiquity of Tertiary Deposits.

Sufficient data have now been stated concerning the local characters of tertiary deposits to show how variable are the strata of this series, and what great difficulties oppose themselves to a satisfactory classification of them

\* These terms are derived from *savane*, (recent,) combined with *du*, (the dawn,) *passé*, (less,) and *plus*, (more.)

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according to their relative antiquity. The methods of inquiry which have been found so successful in the solution of that problem, when applied to secondary strata, are here much less applicable. The mineral character of these deposits is, far more than amongst secondary strata, dependent on the nature of the neighbouring mountains of older rocks, on the condition of the sea, and the state of elevation of the land. No two separate tertiary districts, unless perhaps those which follow the line of the Danube, could be satisfactorily compared by mineral characters alone.

The thickness of the deposits is enormously unequal, and the angles of their inclination and their elevation above the sea afford no resting place in this research. Some help may ultimately arise from the theory of elevation of mountains; but M. de Beaumont's view, which alone seems to apply itself distinctly to this subject, is as yet too embarrassed with objections, and too little examined in detail to be available.

Value of  
zoological  
evidence.

Nothing then remains on which to build hopes of arranging the tertiary series in a regular sequence according to their ages, but the evidence of their organic contents, and accordingly it is in this direction that the efforts of modern Geologists and Naturalists are vigorously exerted.

This being our only probable basis of operations, it will be well to examine its weak points beforehand, lest much labour be lavished on a fruitless undertaking. Difficulties of a very serious nature, and problems not yet solved, nor even entertained by Geologists, perplex the history of tertiary organic remains.

Mode of  
employing  
it in relation  
to older  
geology.

Amongst the older rocks, notwithstanding the general admission of Mr. Smith's views, the organic remains have been chiefly used in reasonings on the condition of the land and sea at certain periods, defined, not by the existence of these organic remains, but by the occurrence of a given sequence of rocks, in which those remains are imbedded. It is true that the classification by superposition has been found wonderfully accordant with the general Geological results of Zoology, but the real dependence of both the practical and the theoretical Geologist is upon the order of superposition. Thus, when the oolitic system is from any cause obscured, the ranges of chalk above and red sandstone below are immediately appealed to. It is true that in such a case the organic remains might very probably equally decide the doubt; but so long as the relation between the organic remains and the strata is known only in its most general terms, and for a whole series of rocks taken together, while the particular modifications of this relation, which should enable us to apply the theory to different strata in a given region, and to the same or different strata in different regions, are yet matter of investigation, it is evident that no Geologist will consider conclusions depending on organic remains alone as having more than half the force of those which combine also the data of superposition. Their use, in short, so far as relates to this question, *viz.* the relative antiquity of deposits, has ever been *supplementary, not principal*. But now we are to take them as our chief guides.

Among the older rocks, such an inquiry, conducted upon the evidence of organic remains alone, would have this advantage, the top of the series to be divided can be clearly defined in the vicinity, though the division may be arbitrary, and so of the base; but in tertiary strata the base can hardly ever be seen, or even safely presumed to be at all known, so many have

been the dislocations preceding them, and so abrupt in their junction with the older strata; neither can their uppermost terms be often assigned from a neighbouring type, because the sea, whose bed is the uppermost term, has long since quitted the vicinity of the deposits.

While considering the organic remains of secondary strata, the most successful analogies have always been established by referring to the nearest well known type, whether the object was to compare the fossils of identical or of different strata. Thus the fossils of Normandy present stronger analogies to those of the South of England than to those of Yorkshire; the chalk of England and France produce a greater number of similar fossils than is common to the chalk of England and Sweden, &c. Also the true relation of the oolitic to the lias fossils is best deduced by comparing them in the same district: the oolite of Dundry should be compared with the lias of Bath, rather than with the lias of Yorkshire or of the Western Islands.

These truths are plain, but not unimportant. They lead directly to a particular mode of prosecuting the investigation. For the identification of strata in distant deposits, we must compare them by intermediate terms; for the determining of the relative antiquity of deposits, we must compare, if possible, the marine or fluviatile organic remains which they contain with both the uppermost and lowermost terms of the series, as they occur in the vicinity. Now the uppermost term of this series is certainly no other than the productions of the neighbouring sea and lakes; but the lowermost term is unknown, for the cretaceous system holds no tertiary fossils. We must therefore *assume* the lowest term, and because of the great number of fossils which have been discovered in the calcaire grossier of Paris, this, the lowest really marine deposit of that region, may be chosen as such. If any strata should hereafter be discovered below this stratum and above the chalk, their relative antiquity may be investigated upon the same principles, but the calcaire grossier will in such a case become the upper term, and perhaps the chalk the lower one. Whenever the inquiry can be prosecuted in agreement with these conditions, and the number of organic remains is considerable, the result may be trusted. The organic remains of terrestrial animals can be useful only in comparing terrestrial deposits, lacustrine animals for fresh-water deposits, and marine animals alone must be compared for marine deposits.

As a general upper term of the tertiary series, we are reduced to take the catalogue of existing marine productions, and we are compelled to reason on this, though in fact, through the uplifting of the bed of the sea in some parts, whole races of shells which were then peculiarly situated, (as, for example, a great number of shells in the Mediterranean and in the German Ocean now are,) were probably destroyed within a short period. In such a case the comparison of the fossils is made with a general catalogue indeed, but one from which many of their peculiar analogues have long since been erased, not by gradual change from general physical causes, but by local events.

May we not apply this general argument to the case of the Vienna basin, as compared with the subapennine formations? Is not the former a whole dedicated gulf, and the latter only the dried margin of a gulf? And should we not in this case find the analogy of the fossil and recent tribes strong in Italy, and much fainter in

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Proper  
mode of  
employing  
it for ter-  
tiary strata

Geology. Ch. II. the valley of the Danube, even though the deposits were of exactly the same age?

Again, if we were to abstract from the catalogue of living shells with which we compare the crag of England, the shells of the Northern European Ocean, what would be the effect upon the numerical results of this comparison? Instead of forty species in a hundred now identical with living forms, there would remain two; and the crag would appear as little related to the existing Fauna of the general ocean as the London clay, which yet is very much more ancient, and, tried by the test of the neighbouring Fauna, appears to be so.

Lastly, it is to be noticed, that even when both the upper term and the lower term of the series is given from a neighbouring type, the application of the principle of the numerical analogy of species to a variety of basins, for the purpose of ascertaining the relative antiquity of distant deposits, demands the admission that the variation of species, on whatever causes this effect depended, has been proportional always, and in all situations, to the time elapsed. Should this be granted unreservedly, without evidence or examination?

Such are a few of the difficulties in the way of determining, by comparison of organic remains with existing forms, the relative ages of the tertiary strata, and we are not aware that this open statement of them should incur the charge of inconsiderate objection. Long experience has proved to us the inestimable value of the legitimate deductions from the study of organic remains with reference to their antiquity; and it is not to check, but to secure the advances of Geologists in this the only avenue to the classification of tertiary strata, that the unknown conditions of the problem are thus pressed upon their attention.

Mr Deshayes's investigations. Were the data upon which the further prosecution of this subject depends not more accurate than those which have been accumulated for the secondary rocks, the determination of the age of tertiary strata in distant basins, with such preliminary difficulties in the general reasoning, must have been indefinitely postponed. But, from various causes, the characters of tertiary shells have been long and carefully studied, and the determination of their species, in consequence of their great number, perfect conservation, and decided general similitude to recent kinds, has been successfully attempted by Lamarck, Brocchi, Sowerby, and other Conchologists. But it is to Deshayes that the Science owes the most lasting obligations of this nature. From the most extended examination of shells both recent and fossil ever attempted, that eminent Conchologist has deduced the most valuable and consistent results which Geology has yet received from any Naturalist, on the subject of the geographical distribution of fossil species, and the numerical ratio of identity between fossil and recent tribes. The Tables which he has constructed from this laborious investigation, are given at length in Lyell's *Principles of Geology*, vol. iii.

The order of deductions in these pages being to a certain degree different, we shall not copy those Tables, nor even the results in the way they are given, yet all the statements to be made here are based entirely on the data of Deshayes. For the sake of a common scale, ratios to one hundred will be introduced when useful. Land and fresh-water species are included, but ultimately, no doubt, they will be separated from the Tables of marine shells.

The number of recent species examined by M.  
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Deshayes, for the construction of his Tables, is 4780; of fossil species 3086; together 7866; but 426 of these were both recent and fossil; therefore the whole number of distinct species examined is 7390; and the ratio of the number of species which are both recent and fossil is as 5.7 to 100.

The proportions of univalve and bivalve shells were found thus:

		Ratio to 100.
Living species....	{ Univalves.....3616	75.6
	{ Bivalves.....1164	24.4
		4780
Tertiary species ..	{ Univalves.....2098	69.1
	{ Bivalves.....938	30.9
		3036

In these lists land and fresh-water shells are included to the number of 1465 recent, 259 fossil, of which

Fresh-water species ..	{ Living bivalves. 118	fossil .. 30
	{ Living univalves. 151	fossil .. 151
Land species .....	Living .....	1196
	fossil ..	78

The fossils are grouped by Deshayes under the following principal localities

1st Division.—Paris, London, Hants, Valognes, Belgium. The fossils of Castel Gomberto and Pauliac are considered the same, nearly, as those of Paris.

2d Division.—Bordeaux and Dax, Touraine, Turin, Baden, Vienna, Angers, Ronca. The fossils of Moravia, Hungary, Cracovia, Volhynia, Podolia, and Transylvania are considered the same, with very few exceptions, as those of Vienna and Baden.

3d Division.—Italy, Sicily, the Crag. The fossils of Perpignan and the Morea are considered the same, with three or four exceptions, as those of Italy.

Tertiary and living species compared.

		Ratio of living species to 100.
Number of species from the Paris basin ....	1122 of which 38 are living	3.4
Bordeaux and Dax. 594 .....	136 .....	22.9
Italy .....	569 .....	41.8
Valognes .....	332 .....	
Touraine .....	298 .....	68 .....
London .....	239 .....	12 .....
Sicily .....	226 .....	216 .....
Angers .....	166 .....	25 .....
Vienna .....	124 .....	35 .....
Crag .....	111 .....	45 .....
Baden .....	99 .....	26 .....
Turin .....	97 .....	17 .....
Belgium .....	49 .....	
Ronca .....	40 .....	3 .....

Arranging these approximate results in the order of their ratios we shall have a descending series of analogies from the Sicilian deposits to the Paris basin.

Thus the analogy of fossil species to the living species is,

Sicily .....	95.0	Allied to existing species in the general ratio of .....	49 to 100
Italy .....	41.8		
Crag .....	40.1	{	18 to 100
Vienna .....	28.2		
Baden .....	26.2	{	Ditto .....
Bordeaux and Dax .....	22.9		
Touraine .....	22.7	{	Ditto .....
Turin .....	17.5		
Angers .....	15.0	{	Ditto .....
Ronca .....	7.5		
London .....	5.0	{	Ditto .....
Paris .....	3.4		
Belgium, Valognes, Castel Gomberto, and Pauliac .....	none stated.	{ Ditto..... 3½ to 100	

In consequence of this comparison, M. Deshayes makes three groups of the tertiary series, according to the ratio of their analogy to existing kinds, as expressed  
4 u



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by the brackets above, and Mr. Lyell, from independent researches of a less extended character, was led to form the same scale of analogies, and, moreover, to separate the Sicilian fossils as still more recent than the others. He therefore divides the most recent group into two, and calls them newer and older pleiocene, (or pliocene,) the middle group he calls miocene, (or miocene,) and the oldest group he calls eocene, as before explained.

Criticism on this scale of analogy would be at present wholly premature, and perhaps not respectful to the eminent Naturalist whose extraordinary knowledge and diligence have presented us with these most beautiful and impressive results. It appears to deserve remark, however, that the inland situations of the Vienna and Baden tertiaries may unfavourably influence the comparison for the fossils in these localities, from the causes before stated; and, perhaps, it may appear, if that circumstance could be properly compensated, that these localities should be removed from their association with Bourdeaux; and joined to the subapennine deposits, according to what seems to have been the inference of the observers on the spot.

Relation of  
tertiary  
shells to  
those in the  
basin of  
Paris;

The subject may be contemplated in another point of view; instead of inferring the relation of the fossil shells to one common upper term, *viz.* the shells of the actual seas, they may be compared to what has been assumed as the lowest term of the series, the basin of Paris. Because of the very great and admitted resemblance of the shells of Paris, London, Valognes, and Belgium, these may be grouped together and we shall have the lowest tertiary epoch yet clearly made out represented by 1238 species, of which 42 are recent, and 46 are found in the deposits above them.

Ratio to 100.

Shells of Bourdeaux and Dax	594, of which 27 are also Parisian, 4.6 nearly.
Touraine	298 ..... 8 ..... 2.6
Angers	166 ..... 7 ..... 4.2
Vienna	124 ..... 3 ..... 2.4
Baden	99 ..... 2 ..... 2.0
Turin	97 ..... 7 ..... 7.0
Ronca	40 ..... 10 ..... 25.0
Sicily, Italy, the Crag	777 ..... 4 ..... 0.6

From this Table we have the following scale for comparison with that previously given, the analogies to the Parisian formation increasing downwards.

Sicily, Italy, the Crag	.....analogy 0.6
Baden	..... 2.0
Vienna	..... 2.4
Touraine	..... 2.6
Angers	..... 4.2
Bourdeaux and Dax	..... 4.6
Turin	..... 7.0
Ronca	..... 25.0

The accordance of the two scales is very remarkable, and by both of them Ronca, as Deshayes conjectured, appears to demand a place in the Parisian group. Vienna, Baden, and Touraine here appear less related to the Parisian group.

to those of  
Touraine  
and Dax.

The relation of the Touraine fossils and the Bourdeaux and Dax fossils to the subapennine formations appears to be almost exactly the same; their relation to living types is also almost exactly the same. It is therefore evident that these beds may be joined together to make a new common term. We shall then have 743 species, and the analogy to this common term is for

Vienna	..... 85.5
Baden	..... 49.5

Turin	..... 47.4
Angers	..... 30.7
Subapennine	..... 22.7
Parisian epoch	..... 4.0

## The analogy of the

Vienna and subapennine fossils in	40
Turin and subapennine	29
Bourdeaux and subapennine	22.5
Touraine and subapennine	23.4

The general result of these numerical comparisons would seem to give the following scale of antiquity results amongst the several deposits.

Sicilian deposits.	Newer pleiocene.	Lyell's Name.
Crag — Subapennine deposits.	Older pleiocene.	Pleiocene.
Vienna beds.		
Touraine — Bourdeaux and Dax — Baden — Turin.		Miocene.
Angers.		
The Parisian and London deposits.		Eocene.

Having thus shown from M. Deshayes's data, the origin of the groups which he uses, and of the names of Mr. Lyell, we may present the following general results of the investigation of those authors, and refer to themselves for abundance of further information.

Eocene, or Parisian period. This should perhaps be considered as strictly applicable to the lower marine formation of the Paris basin, because it is almost wholly on the shells of that formation that the classification is founded.

Number of species of shells of this period	1238
Number of species also found in the miocene period	66
Number of species also found in the miocene and in the pleiocene period, and which may therefore be considered as characteristic of the whole tertiary system	17
Number of species identical with living kinds	42

## Miocene Period.

Number of species of shells	1155
Number of species common to the miocene and the two other epochs	134
Real number of species of this period	1021
Number of species also found in the pleiocene period	196
Number of species identical with living kinds	176

## Pleiocene Period.

Number of species of shells	777
Number of species identical with living kinds	350
Whole number of species of shells of the tertiary system	3036

Names of the seventeen shells which are characteristic of the tertiary system.

Four extinct or unknown in a recent state	<ul style="list-style-type: none"> <li>Dentalium coarctatum</li> <li>Tornatella inflata.</li> <li>Bulimus terebellatus.</li> <li>Corbula complanata.</li> <li>Dentalium entale.</li> <li>strangulatum.</li> <li>Fissurella græca.</li> <li>Bulla lignæria.</li> <li>Rissoa cochlearia.</li> <li>Murex fistulosus.</li> </ul>
Thirteen still living	<ul style="list-style-type: none"> <li>tubifer.</li> <li>Polymorphina gibba.</li> <li>Triloculina oblonga.</li> <li>Lucina divaricata.</li> <li>gibbosula.</li> <li>Isocardia cor.</li> <li>Nucula margaritacea.</li> </ul>

## Organic Remains of the Tertiary Strata.

The statement previously made that M. Deshayes has himself examined 3036 species of tertiary fossils, must be a sufficient reason for not following in respect of these strata the plan adopted for the less numerous

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organic remains of the secondary and primary rocks. There is indeed not the same inducement or utility in such extended lists of tertiary fossils. They would not add any thing to the knowledge of periods given by the investigation which we have just ended, and the general resemblance in tertiary fossils of all ages and localities is too great to confer any particular interest on the enumeration of species. There is, probably, no more remarkable statement in any Science, than that of all the 3036 species of tertiary shells, *not one* should be found in any of the older strata. This statement could only be made and can only be verified by a skilful Conchologist; but the eye least practised in such observations can recognise the same proposition in another form. Many of the tertiary genera of fossil shells, and especially those which predominate in these strata, are either utterly unknown or very seldom seen in secondary strata, and thus whole tribes of shells are instantaneously pointed out, by one who is no Conchologist, as tertiary fossils.

The most useful lists of tertiary fossils will be such as are capable of direct comparison on leading points with catalogues formerly given for the secondary rocks. For this, the generic name and number of species must in general suffice. The marine deposits should be separated from those of fresh-water. The numbers of the species of shells are taken from Deshayes's Tables. The remainder from Brongniart, *Tableau des Terrains*

*Marine Deposits.*

PLANTS, from M. Adolphe Brongniart.

<i>Agamia.</i>	Species.	<i>Phanerogamia Monocotyledonea.</i>	Species.
Conferites .....	2	Potamophyllites .....	1
Fucoides .....	11	Flabellaria .....	1
<i>Cryptogamia.</i>		Anthothetes .....	2
Equisetum .....	1	Culmites .....	2
Tenopteris .....	1	<i>Phanerogamia Dicotyledonea.</i>	
<i>Phanerogamia Gymnosperma.</i>		Exogonites .....	1
Pinus .....	2	Phyllites .....	7
<i>Phanerogamia Monocotyledonea.</i>		Juglans .....	1
Caulites .....	1	Carpolithes .....	1
Zosterites .....	2		

POLYPARIA, chiefly from Brongniart and Goldfuss

Caryophyllia .....	1*	Eschara .....	1
Turbinolia .....	4	Ovulites .....	1
Astræa .....	2	Lunulites .....	3
Fungia .....	1	Alveolites .....	1
Madrepora .....	1	Favosites .....	1
Flustra .....	1	Iscia .....	1
Orbitulites .....	1	Isis .....	2
Dactylopora .....	1	Glaucanome .....	4
Polytripes elongata .....	1		

## RADIARIA.

Echinus .....	1	Nucleolites .....	1
Scutella .....	3	Galerites .....	2
Clypeaster .....	9	Spatangus .....	4
Cassidulus .....	2	Asterias .....	1

*Articulated Animals.*

## CRUSTACEA.

Atelecyclus .....	1	Palinurus .....	1
Leucosia .....	1	Sphæroma .....	1
Inachus .....	1		

## ANNULOSA.

Serpula .....	4	Spirorbis .....	1
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## CIRRIPEDA.

Balanus .....	5	Pyrgoma .....	1
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*Molluscan Animals.*

## CONCHIFERA.

*Plagymyond.*

Species.	Species.
Aspergillum . . . . .	1
Clavagella . . . . .	9
Teredina . . . . .	2
Teredo . . . . .	5
Pholas . . . . .	9
Fistulana . . . . .	7
Solen . . . . .	19
Pholadomya . . . . .	1
Panopæa . . . . .	3
Mya . . . . .	5
Thracia . . . . .	4
Hemicyclostera . . . . .	2
Lutraria . . . . .	6
Macra . . . . .	14
Mesodesma . . . . .	7
Erycina . . . . .	23
Cassatella . . . . .	24
Amphidesma . . . . .	1
Corbula . . . . .	35
Pandora . . . . .	3
Saxicava . . . . .	11
Petricola . . . . .	10
Venerupis . . . . .	6
Sanguinolaria . . . . .	2
Panmichia . . . . .	4
Panmichia . . . . .	1
Tellina . . . . .	54
Corbis . . . . .	2
Lucina . . . . .	59
Donax . . . . .	15
Astarte . . . . .	19
Cypina . . . . .	7
Cytherea . . . . .	59
Venus . . . . .	43
Venercardia . . . . .	40
Cardium . . . . .	39
Cypicardia . . . . .	7
Isocardia . . . . .	3
Cucullæa . . . . .	2
Atræa . . . . .	54
Pectunculus . . . . .	27
Nucula . . . . .	23
Umo . . . . .	2
Anodonta . . . . .	1
Chama . . . . .	20
Tridacna . . . . .	2
Modiola . . . . .	21
Mytilus . . . . .	15

*Myomyona.*

Pinna .....	3	Grypha .....	3
Perna .....	4	Ostrea .....	72
Avicula .....	5	Himmet .....	4
Lima .....	13	Vulsella .....	1
Pecten .....	60	Placuna .....	1
Plicatula .....	7	Anomia .....	8
Spondylus .....	9		

*Brachypoda.*

Crania .....	3	Thecidia .....	1
Terebratula .....	18		

*Pteropoda.*

Hyalea .....	2	Cleodora .....	3
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*Gastropoda.*

Chiton .....	1	Turritella .....	45
Dentalium .....	34	Proto .....	4
Patella .....	10	Corithum .....	220
Umbella .....	1	Triforis .....	2
Parmophilus .....	2	Pleurotoma .....	156
Emarginula .....	11	Turbanellus .....	3
Fissurella .....	8	Cancellaria .....	42
Pileopsis .....	6	Fasciolaria .....	5
Hippomyx .....	12	Fusus .....	111
Crepidula .....	3	Pyruia .....	21
Calyptæa .....	15	Struthiolaria .....	1
Bulla .....	2	Ranella .....	5
Bulla .....	23	Murex .....	89
Pileolus .....	2	Triton .....	25
Neritina .....	17	Rosellaria .....	8
Nerita .....	16	Strombus .....	9
Natica .....	41	Cassidaria .....	8
Sigaretus .....	4	Cassia .....	15
Stomatella .....	1	Ricinus .....	1
Haliotis .....	1	Purpura .....	4
Tornatella .....	11	Monoceros .....	1
Pyramidella .....	8	Harpa .....	2
New genus .....	1	Dolium .....	1
Vermetus .....	1	Buccinum .....	95
Siliquaria .....	6	Terebra .....	16
Scapharia .....	22	Columbella .....	4
Delphinula .....	12	Mitra .....	66
Solarium .....	16	Voluta .....	32
Omalaxos .....	5	Margmella .....	17
Trochus .....	70	Volvæ .....	2
Pleurotomaria .....	1	Ovula .....	6
Monodonta .....	8	Cyprea .....	19
Turbo .....	34	Oliva .....	13
Littorina .....	10	Ancillaria .....	9
Planaxis .....	5	Terebellum .....	2
Phasianella .....	4	Conus .....	49



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<i>Cephalopoda.</i>		
Species.		Species.
<i>Nautilus</i> .....	1	50 other genera in- cluding .....
<i>Nautilus</i> .....	4	No belemnites, ammonites, hamites, nautilus, turritiles, &c
<i>Nautilus</i> .....	21	

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## FISHES.

Of fishes it is estimated that 100 species belong to the marine tertiaries.

Of reptiles there are 6 crocodiles, 5 trionyx, 4 emys, 1 testudo.

Of cetacea; lamantin, delphinus 4 species, xiphius planirostris, balena, Lin., 2 species.

Of other mammalia, phoca, trichilecus.

## General Summary.

2975 species.

Plants .....	36	species.
Polyparia .....	27	
Radiaria .....	23	
Crustacea .....	5	
Annulosa .....	5	
Curripeda .....	6	
Conchifera plagyrymona .....	736	
mesomyona .....	190	} 948
brachiopoda .....	22	
Pteropoda .....	5	} 27 17 mollusca.
Gasteropoda holostomata .....	469	
solenostomata .....	1066	
Cephalopoda .....	259	
Pisces .....	100	
Reptilia .....	16	
Cetacea .....	8	
Other Mammalia .....	2	

## Lacustrine Tertiaries.

Their age to be inferred from the remains of aquatic races.

\* As the marine shells afford the best or rather the only grounds for plausible deductions concerning the relative ages of the tertiary strata deposited from the sea, so the fresh-water shells and land shells must be employed to indicate the relative age of the many lacustrine deposits which diversify the tertiary districts, and cannot always, by any rule of superposition, be referred to either of the lacustrine deposits of Paris. In this research the plants also yield highly valuable evidence, but the land mammalia found with them ought surely to be excluded from the data which are to determine the age of the lacustrine sediments; because the changes of their races may, for ought we know at present, have been governed by wholly different conditions from those which affected the fresh-water or land shells and plants. Indeed, the case of shelly and osseous marl at Market Weighton, as well as every peat bog containing the Irish elk, proves that this suggestion is well founded. The era of the quadrupeds is to be determined from that of the lakes, not assumed to help out the deficient evidence concerning these latter.

A few cases, selected from the great number of tertiary lacustrine deposits, for the sake of some peculiar facts which they display, may now be introduced, to illustrate the condition of the surface of the land during the tertiary epoch. In general it is to be observed that, just as at the present day lakes sometimes occur on certain streams, in several parts of the valley, at different heights above the sea, and spread their waters over the Jura limestone, chalk, tertiaries, or primary strata, according to the nature of the country, so it was in the older time; and no criterion of the age of a fresh-water deposit is to be drawn from the marine nature of the strata on which it rests beyond the mere inference that it was posterior to such strata. If, as must frequently happen, the cir-

cumstances of these different lakes are unlike, the deposits in them may be related neither by similarity of order, nor identity of composition, but it is probable that some analogy will be traceable in their organic remains.

In the basin of Paris, gypsum occurs only in the lower fresh-water deposit, yet the gypsiferous fresh-water deposit of Auvergne, is supposed by Brongniart to be of the age of the upper fresh-water deposits.

The fresh-water district of central France occupies considerable tracts along the lines of the Loire and the Allier, and is extended Northwards on the latter river, so as to approach towards the proper basin of Paris. The interesting phenomena presented by these deposits, where they have been subjected to volcanic agency about Clermont, the Cantal, and Puy in Velay, will be mentioned hereafter. Along the Allier, granite is the general basis of the fresh-water strata, which consist of sandstone and conglomerate, containing pebbles of all the primary rocks of the vicinity, but not of the volcanic rocks. Above these are green and white very finely foliated marls, full of the small bivalve crustaceous shells of cypris, thin tufaceous limestones, sometimes full of the larva—cases of phryganeidæ; and the highest group of all in a few places is composed of gypsiferous marls. The most singular fact mentioned by Messrs. Lyell and Murchison, in their description of this country, is the remarkable condition of two of these groups. The lowest conglomerate series puts on almost exactly the appearance of the English old red sandstone, with its purple and green spotted marls, and even its nodular limestone or cornstone; and the limestone in the upper part of the series actually becomes oolitic at Vichy and Gannat, and yields a building stone like that of Bath, and of equal beauty; soft in the quarry, but gathering hardness by exposure. With what astonishment would the Geologist, acquainted with the fossils of the English oolite, gather in this oolite of Gannat, land shells and bones of quadrupeds, like those of the gypsum of Montmartre!

The lacustrine formation of the Cantal, rests in the same manner upon primary rocks, with sandy and gravelly beds below, gypsiferous marls, beds of flint and limestone above. This fresh-water limestone, and its accompanying flints, are described by Mr. Lyell as possessing a strong resemblance in mode of arrangement to the marine chalk and flint; the flint of the fresh water, black within, white without, and undergoing the same changes of superficial colour on exposure as the chalk flints of England.

The same Geologists have been very successful in Provence, tracing the fresh-water deposits of Aix in Provence, which have yielded a large number of fossil insects, some fishes, and land plants of existing genera. M. De Serres also has described this locality, and studied the insects with attention. The general basis of the Aix tertiaries, is a rock of the oolitic system, inclined and contorted in position, with gryphæa, belemnites, and ammonites. The lacustrine deposits are in the lower part a series of carboniferous limestones and shale, with stony bituminous coal in several seams which altogether amount to five feet in thickness. The limestone is compact, grey, blue, and black, and resembles the mountain limestone of England. Fresh-water shells (cyclades, melania planorbis unio) accompany these beds, and gyrogonites are found in the coal itself. Miocene sandstones and shales, with earthy limestone and lime-  
neæ, come on above; and these are succeeded by red marl and fibrous gypsum, also characterised by the pre-

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sence of limness and planorbes. Under and above the town of Aix, the upper series of the basin is observed to consist of red sandstone and conglomerate, covered by white and pink-coloured marlstone and marl; and above all is a triple succession of gypsum and marls, overlaid by white calcareous marls and marlstone, with calcareo-silicious millstone and resinous flint, containing land and lake shells. It is in these beds that the fossil fish occur abundantly, and leaves and branches of *flabellaria*, *laurus*, *boxus*, &c. are found. The insects are obtained from a parting in the upper gypseous beds. They are, with one exception, all land insects; and from the united testimony of M. De Serres and Mr. Curtis, referable or nearly related to existing genera, principally of the orders diptera and hemiptera, some coleoptera and hymenoptera, but only one lepidopterous insect: sixty-two genera are particularly enumerated by M. De Serres. May we not compare this curious and as yet almost unique fact in tertiary Geology to the collection of insects, leaves, and branches, which, when swept down by Spring or Summer floods, affords a rich harvest to the Entomologist on the borders of the rivers in the North of England?

Tertiary.

The limestone quarries of Enningen, near Schaffhausen, have long been celebrated for abundance of mammalia, birds, reptiles, fishes, insects, and plants, identical or very similar to existing kinds. The section of the whole deposit is given by Mr. Murchison, who brought from this locality, in 1828, one of the most remarkable fossils which has ever been found—the entire and connected skeleton of a fox. The upper quarries offer a section of thirty feet, the beds changing downwards from brown clay into cream-coloured indurated marl, and afterward into a fissile fetid marlstone, containing flattened shells of planorbis, small limnææ, and cyprides; to these succeeds light-coloured, fetid, calcareous building stone, beneath which is a finely laminated bed, containing insects, cypris, shells of anodon, and many plants; then follow two thin beds of fetid limestone, in the upper of which a large tortoise was found, and in the lower one the fox. Below are slaty marls and marlstones, limestone, and building stone, with a repetition of finely laminated layers of marl, with plants and fishes; the general base is the molasse of Switzerland. Excepting this fox, which is very much allied to the common fox of Europe, all the other quadrupeds found here are rodentia. The insects and plants belong to European genera.

These descriptions, of some of the most interesting lacustrine deposits, will render it unnecessary to particularize other numerous cases in Switzerland, Germany, Hungary, Italy, and Spain, which present nearly the same phenomena, and appear to occupy the whole interval of time from the lower fresh-water formation of Paris to the diluvial era; and to be represented by an equally continuous series of detached desiccated lakes from that era to the present time.

Lignite.

There is, however, another kind of fresh-water deposit which requires a short notice. Lignite, or wood coal, has long been known in France, in connection with the plastic clay group and other more recent strata, and also in the Isle of Wight. The same kind of carbonaceous deposit is of value in the molasse of Switzerland, and very extensively spread over the North of Germany, and in the Valley of the Rhine; it also interminates extensively the marine tertiary of the basin of Vienna and the border of the Carpathians; lignitic coal has therefore been considered as even peculiar to the

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tertiary era. This is not quite correct, yet the generalization is of more importance than perhaps we may at present perceive.

The whole mass of these lignites is made up of land plants, mostly or wholly of dicotyledonous tribes, and they are accompanied by marls, land and fresh-water shells, and, in places, by the bones of paleotheria, anthracotheria, beaver, &c. The fixing of their relative age is hardly possible by evidence drawn from themselves alone, for the shells and plants are few, and the quadrupedal remains very local. If we attempt to fix their date by that of the marine strata which they divide, the uncertainty of the latter datum must, in a great measure at present, frustrate the attempt. Perhaps the most recent deposit of this kind mentioned on the Continent, is that described by De Beaumont as associated with the older diluvium, as it has been considered, which that author ascribes to the uplifting of the Western Alps. This deposit bears marks of slow and tranquil accumulation in a lake, contains planorbes in the layers of clay which alternate with it, and sometimes shows as many as four beds; it rests on and is covered by pebbles, which indicate violent watery action.

It is highly probable that lignite has been formed at many periods, and that deposits of this kind will be found at intervals from the plastic clay, through the diluvial gravel and clays to the modern alluvial peat bogs, which they so much resemble in alternation and repetition of materials, paucity of shells, occasional occurrence of quadrupedal remains, and almost every obvious circumstance.

Bovey Tracey, in Devonshire, is the only locality in England where tertiary lignites are worth working; the exact Geological age of this deposit is not known at present. Pipe-clay of some value lies with it. Dr. Miller, in the *Phil. Trans.* vol. li. describes this deposit in a very interesting manner. The whole series dips to the South about twenty inches in a fathom. The perpendicular thickness of these strata, including the beds of clay with which they are intermixed, is about seventy feet. There are about six of each, and they are found to continue Eastward, in an uninterrupted course, to the village of Little Bovey, a mile distant, and probably much further. The strata of coal, near the surface, are from eighteen inches to four feet thick, and are separated by beds of brownish clay, nearly of the same dimensions, but diminishing in thickness downwards, in proportion as the strata of coal grow larger; and both are observed to be of a more compact and solid substance in the lower beds. The lowermost stratum of coal is sixteen feet thick; it lies on a bed of clay, under which is a sharp green sand of seventeen feet thick, and under that, a bed of hard coarse clay, into which they have bored but found no coal. From the sand arises, a spring of clear blue water, which the miners call mundic water, and a water of the same kind, trickling through the crevices of the coal, tinges the outside of it with a blue cast. (Phosphate of iron.)

Amongst the clay, but adhering to the coal, are found lumps of a bright yellow loam, which burn with an agreeable scent. (Retinasphalt.) Some of the coal is black, and nearly as heavy as pit coal; this is called stone coal; but the most remarkable sort resembles wood in the grain and appearance so much as to be called wood or board coal. Some plants like grass and reeds lie in the alternating clays, which are in part carbonaceous.

The following section of the Meissner by M. Herudenberg (*Leonhard Taschenbuch*, 1817) gives the most exact relations of the brown coal and basalt of that celebrated locality.

1. Dammerde.
2. Greenstone and basalt, 50 to 80 fathoms . . . . . 320 to 480 feet.
3. Schuil, (blind coal), a bituminous laminated clay, hardly to be distinguished from true coal . . . . .  $\frac{1}{2}$  to 5 feet.
4. Kohlenstr., in all 3 to 14 fathoms thick, viz.
 

<ul style="list-style-type: none"> <li>a. Stangenkohle (prismatized) . . . 1 to 4 ft. . .</li> <li>b. Glanzkohle (sp. gr. 1.438) . . . 3 to 18 ft .</li> <li>c. Pechkohle (sp. gr. 1.346) . . . 3 in. to 3 <math>\frac{1}{2}</math> ft.</li> <li>d. Brownish black (sp. gr. 1.259) 3 to 4 ft. . .</li> <li>e. Light brown light coal (sp. gr. 1.230) . . . . . 4 to 8 fath..</li> </ul>	}	3 to 14 fath.
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- f. Fossil wood, called stockwerk 6 in. to 1 ft.
5. Liegende, (sill or sole of the coal,) sp. gr 2.515
6. Trieband . . . . .  $\frac{1}{2}$  fathom.
7. Blue marl, on the East of the mountain, with gypsum . . . . . 10 to 15 fath.
8. More or less friable sandstone 1 fathom, then sandstone to the foot of the mountain on the East side, but on the West side muschelkalk.

### Organic Remains of Lacustrine Tertiaries.

PLANTS from M. Adolphe Brogniart.

## Agencia

- |                                    |   |
|------------------------------------|---|
| <i>Cryptogamia cellulosa.</i>      |   |
| Muscites Tournaini . . . . .       | Armissan near Narbonne                        |
| squamatus . . . . .                | Longjumeau near Paris.                        |
| <i>Crypt. vasculosa.</i>           |   |
| Equiset brachyodon . . . . .       | Armissan.                                     |
| Filicites polybotrya . . . . .     | Ditto   |
| Lycopodites squamosus . . . . .    | Paris.  |
| Chara Lemani . . . . .             | St. Ouen near Paris                           |
| tuberculosa . . . . .              | Isle of Wight                                 |
| medicaginula . . . . .             | { Montmorency, Sanois, Trappes<br>near Paris. |
| helicteres . . . . .               | Pleurs, Département de l'Aisne                |
| <i>Phanerog. gymnosperma.</i>      |   |
| Pinus pseudostrobus . . . . .      | Armissan                                      |
| Taxites Tournaini . . . . .        | Ditto.  |
| <i>Phanerog. monocotyledonra.</i>  |   |
| Smilacites hastata . . . . .       | Ditto.  |
| Flabellaria Lamanonis . . . . .    | Aix en Provence                               |
| Endogenites . . . . .              | Montmartre                                    |
| Poacites . . . . .                 | Aix   |
| <i>Phanerog. dicotyledonra</i>     |   |
| Comptonia dryandraefolia . . . . . | Armissan                                      |
| Betula dryadum . . . . .           | Ditto   |
| Carpinus macroptera . . . . .      | Ditto.  |
| Phyllites lavigata . . . . .       | Aix, Armissan, Pavia, &c                      |
| Gesni . . . . .                    | Aix.  |
| Nymphaea arethusa . . . . .        | Longjumeau.                                   |
| 2 Culmities anomelus . . . . .     | Ditto   |
| Carpolites thalictaules . . . . .  | Ditto, Isle of Wight.                         |
| ovulum . . . . .                   | Longjumeau.                                   |
| Exogenites . . . . .               | Palaiseau.                                    |

## CONCHIFERA

- |                               |                             |
|-------------------------------|-----------------------------|
| <i>Unio Solandri</i> , Sow    | Isle of Wight, Hordwell     |
| <i>Cyclas</i>                 | Aix en Provence.            |
| <i>Anodonta Lavateri</i>      | Cœningen                    |
| <i>Mya ? gregaria</i> , Sow   | Headdon Hill.               |
| <i>Cardula nitida</i> , Sow   | Isle of Wight               |
| <i>Cyrena pulchra</i> ?       | Hamptstead Bay; <b>Skye</b> |
| <i>Mytilus Bizarri</i> , Sow. | Hordwell.                   |

**MOLLUSCA.**

**Gastropoda.**

- Planorbis rotundatus*, Sow. . . . . Paris, Salinella, (Gard,) Quercy.  
*cornu* . . . . . Paris.  
*eumphalus*, Sow. . . . . Isle of Wight.  
*prevostianus* . . . . . Ditto, Paris.

**Planorbis promueus. . . . . Salinelle.**

- |                                      |  |
|--------------------------------------|--|
| <i>Planorbis promeneus</i> .....     | Salinelle.                                       |
| <i>compressus</i> .....              | Ditto.   |
| <i>leas</i> .....                    | Isle of Wight, Fécit.                            |
| <i>cylindricus</i> , Sow. ....       | Isle of Wight.                                   |
| <i>Limæna fusiformis</i> , Sow. .... | London Hall.                                     |
| <i>minima</i> , Sow. ....            | Ditto.   |
| <i>maxima</i> , Sow. ....            | Binsland.  |
| <i>longiscata</i> , Lam. ....        | Headon.  |
| <i>pyramidalis</i> , Sow. ....       | Ditto.   |
| <i>columellaris</i> , Sow. ....      | Hordwell.  |
| <i>cornea</i> .....                  | Paris. Collé ou Siennais.                        |
| <i>fabulum</i> .....                 | Paris.   |
| <i>ventricosa</i> .....              | Ditto, Bruers. (Chat.)                           |
| <i>inflata</i> .....                 | Bruers.  |
| <i>cylindrus</i> .....               | Ditto.   |
| <i>strigosa</i> .....                | Le Locle near Neuchâtel.                         |
| <i>elongata</i> .....                | Paris.   |
| <i>acuminata</i> .....               | Ditto.   |
| <i>æqualis</i> .....                 | Salinelle.                                       |
| <i>pygmaea</i> .....                 | Ditto.   |
| <i>ovum</i> .....                    | Paris.   |
| <i>Paludina affinis</i> .....        | Salinelle.                                       |
| <i>impura</i> .....                  | Quercy.  |
| <i>hummeri</i> .....                 | Isle of Wight, Bouxweiler.                       |
| <i>carinata</i> .....                | Paris.   |
| <i>Ancylus elegans</i> .....         | Hordwell.  |
| <i>deperditus</i> .....              | Salinelle.                                       |
| <i>Melania fasciata</i> .....        | Isle of Wight.                                   |
| <i>Melanopsis carinata</i> .....     | Newport, Isle of Wight.                          |
| <i>brevis</i> .....                  | Hordwell, &c                                     |
| <i>Phasianella orbicularis</i> ..... | Shalcomb, Isle of Wight                          |
| <i>angulosa</i> .....                | Ditto.   |
| <i>minuta</i> .....                  | Ditto.   |
| <i>Potamidum Lamarckii</i> .....     | { Paris, Aurillac, Nonette, (non)<br>{ Issouere. |
| <i>acutum</i> .....                  | Isle of Wight.                                   |
| <i>ventricosum</i> .....             | Ditto.   |
| <i>Indusia tubiculata</i> ? .....    | Moulins, Auvergne, Collé                         |
| <i>Cyclostoma truncatum</i> .....    | Paris, Carnetin.                                 |
| <i>elegans antiquum</i> .....        | Paris.   |
| <i>numa</i> .....                    | Ditto  |
| <i>Helix globosa</i> .....           | Shalcombe, Isle of Wight.                        |
| <i>Lemani</i> .....                  | Paris.   |
| <i>Desmarestina</i> .....            | Ditto  |
| <i>Ramondii</i> .....                | Orleans, Auvergne                                |
| <i>Cocqui</i> .....                  | Ditto, ditto                                     |
| <i>Bulimus pygmaeus</i> .....        | Paris.   |
| <i>terebia</i> .....                 | Ditto.   |
| <i>atomus</i> .....                  | Paris, Le Puy.                                   |
| <i>pusillus</i> .....                | Ditto.   |
| <i>Pupa Defranci</i> .....           | { Paris and Auvergne,<br>{ in a piperine         |

ARACHNIDA, INSECTA, &c.

- |                         |                  |
|-------------------------|------------------|
| Aranea .....            | Aix en Provence. |
| Phrynus.                |                  |
| Colcopt Dytiscus.       |                  |
| Staphylinus.            |                  |
| Hyprestis               |                  |
| Melolontha.             |                  |
| Cureulionidæ .....      | 10               |
| Trogonta.               |                  |
| Hylaphagidæ.....        | 5                |
| Orthoptera .....        | 8                |
| Hemiptera .....         | 20               |
| Neuroptera Libellulidæ. |                  |
| Hymenoptera .....       | 8                |
| Lepidoptera .....       | 2                |
| Diptera .....           | 15               |

## FISHES.

- |                         |                         |
|-------------------------|-------------------------|
| Mugil cephalus.....     | Aix in Provence.        |
| Pereca minuta.....      | Ditto and Paris.        |
| Cyprinus squamatus..... | Ditto, ditto.           |
| "    bipunctatus.....   | Cöningen.               |
| "    jisei.....         | Ditto.                  |
| "    capito.....        | Ditto.                  |
| "    marmoratus.....    | Paris.                  |
| "    ichne.....         | Rothenburg. (Schubert.) |
| "    tinea.....         | Cadix.                  |

Geology. (h. II.)	<i>Fæcia Lanthea</i> .....	Paris.
	<i>Aurumurus macrocephalus</i> ..	Ditto.
	<i>Knox</i> .....	Ceningen.
	<i>Amia ignota</i> .....	Ditto.

## REPTILES.

<i>Crocodylus gypsurum</i> , Cuv. ....	Paris, analogous to alligator.
<i>Argentum</i> , Cuv. ....	Argenton, ditto.
<i>Salamandra gigantea</i> .....	Ceningen.
<i>Triton palustris</i> .....	Ditto.
<i>Rana</i> .....	Ditto.
<i>Trionyx gypsurum</i> , Cuv. ....	Paris.
<i>Mauoir</i> .....	Aix and Paris.
<i>des molasses</i> .....	{ La Grave, L'Agnois, Le Quercy, Haute Vigne, (in Lot and Gar- ronne,) Castelnau.
<i>Emys gypsurum</i> , Cuv. ....	Paris.
<i>Testudo</i> of Aix .....	Aix.

## BIRDS.

Several species .....	Paris, Auvergne, Ceningen.
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## MAMMALIA.

<i>Palmætherium magnum</i> .....	{ Paris, La Grave, Dordogne, (also Binstead, Isle of Wight )
<i>medium</i> .....	Ditto.
<i>crassum</i> .....	Ditto.
<i>latum</i> .....	Ditto.
<i>minus</i> .....	La Grave, Paris.
<i>minimum</i> .....	Paris.
<i>auchanense</i> .....	Orleans.
<i>lesclanum</i> .....	Iscl near St. Pajoul.
<i>Anoplotherium commune</i> .....	{ Paris, (also Binstead, Isle of Wight )
<i>secunda</i> .....	Paris.
<i>Xiphodon gracile</i> .....	Ditto.
<i>Dichobunus leporinus</i> .....	Ditto.
<i>mirans</i> .....	Ditto.
<i>obliquus</i> .....	Ditto.
<i>Chæropotamus Parisiensis</i> .....	Ditto.
<i>Anthracotherium velatum</i> .....	Puy en Velay.
<i>Lophodon major</i> .....	{ Argenton, Iscl, Soisson, Gannat, Montabuzard
<i>secundarius</i> .....	Argenton.
<i>minor</i> .....	Paris.
<i>pygæus</i> .....	Ditto.
<i>maximus</i> .....	Bastberg near Bouxweiler.
<i>secundus</i> .....	Bastberg.
<i>Montpelus</i> .....	Boutonnet, Montpellier.
<i>quintus</i> .....	Argenton.
<i>Canis Parisiensis</i> .....	Paris.
<i>Vulpes</i> .....	Ceningen.
<i>Genette des Platrières</i> .....	Paris.
<i>Coati des Plat.</i> .....	Ditto.
<i>Didelp. Parisiensis</i> .....	Ditto.
<i>Ecureuil des Plat.</i> .....	Ditto.
<i>Loir des Plat.</i> .....	Ditto.
<i>second</i> .....	Ditto.

## Lignitic Tertiaries.

## PLANTS. (No marine.)

<i>Coniferae.</i>	
<i>Pinus sphaerocarpa</i> .....	Erleben near Helmstedt.
<i>ovata</i> .....	Walch in Bohemia.
<i>familiaris</i> .....	Trblitz in Bohemia.
<i>Taxites acicularis</i> .....	The Meissner.
<i>tenuifolia</i> .....	Comothau in Bohemia.
<i>diversifolia</i> .....	Cassel.
<i>Langendorffii</i> .....	Nidda near Frankfurt.
<i>Jugiperæa brevifolia</i> .....	Comothau.
<i>scutifolia</i> .....	Ditto.
<i>Paluma</i> .....	Schmetzma in Bohemia.
<i>Thuya gracilis</i> .....	Comothau.
<i>Langendorffii</i> .....	Nidda.
<i>gracilis</i> .....	Perutz. (Bohem.)
<i>Nyctæ.</i>	
<i>Potamoxyllis medietaria</i> .....	Mont Rouge near Paris.
<i>Palme.</i>	
<i>Palmetum schinatus</i> .....	Wally near Soisson.

<i>Flabellaria raphifolia</i> .....	Hering in Tynol, Lammann, Vi- assent near Soisson.
<i>Pheniceites pumila</i> .....	La Chartreuse de Soisson. (Velay.)
<i>Cocos (Parkinsonia)</i> .....	(Sheppey.)
<i>Faujasi</i> .....	Liblar near Cologne.
<i>Burtini</i> .....	Wolouge near Brumda.
<i>Monocotyled. incerta.</i>	
<i>Endogenites</i> .....	Liblar, Horgen near Zurich.
<i>(Amomocarpum depressum)</i> ..	(Sheppey.)
<i>(Pandancarpum pyramidat.)</i> ..	(Ditto.)
<i>Dicotyledoneæ.</i>	
<i>Amnaceæ.</i>	
<i>Comptonia acutifolia</i> .....	Comothau. (Bohemia.)
<i>Salix</i> ? .....	Nidda.
<i>Populus</i> ? .....	Ditto.
<i>Castanea</i> ? .....	Menat.
<i>Ulmus</i> .....	Comothau.
<i>Juglandæ.</i>	
<i>Juglans ventricosa</i> .....	Nidda.
<i>lavigata</i> .....	Ditto.
<i>Aceriæ.</i>	
<i>Acer Langendorffii</i> .....	Ditto.
<i>Dicotyl. incerta.</i>	
<i>Exogenites</i> .....	Universal.
<i>Phyllites cinnamomifolia</i> .....	Meissner.
<i>Carpolithes (many)</i> .....	Nidda.
<i>Leaves, &amp;c. (many)</i> .....	Ditto.

## CONCHIFERA.

<i>Unio ovatus</i> , St. ....	Switzerland.
<i>Cyclas palustris</i> .....	Ditto.
<i>Cyrena antiqua</i> .....	St. Marguerite. (Dieppe.)
<i>tellinoides</i> .....	Soissons.
<i>cuneiformis</i> .....	Ditto.
<i>(rawfordi)</i> .....	Irawadi.
<i>Ostrea Belovacina.</i>	
<i>incerta</i>	

## MOLLUSCA.

<i>Nerita globulus</i> .....	Epernay.
<i>pistorinus</i> .....	Ditto.
<i>subena</i> .....	Ditto, Soissonois, &c.
<i>Ampullaria Faujasii</i> .....	St. Paulet. (Gard.)
<i>Melanopsis buccinoides</i> .....	{ Epernay, Soissons, Cui- seau, Headon Hill, Italy, Sisto, &c.
<i>costata</i> .....	Soissons.
<i>Melania triticea</i> .....	Epernay.
<i>Kochi</i> .....	Kepfnach near Zurich.
<i>Paludina virgula</i> .....	Epernay.
<i>unicolor</i> .....	Soissons.
<i>Desmarestii</i> .....	Paris.
<i>Lamnea longicata</i> .....	Ditto.
<i>Physa antiqua</i> .....	Epernay.
<i>Planorbis rotundatus</i> .....	{ Soissonois, Bagneux, Paris, &c.
<i>regularis</i> .....	Cezenon. (Herault)
<i>incertus</i> .....	Bagneux, Epernay.
<i>punctatus</i> .....	Ditto, ditto.
<i>Prevostinus</i> .....	Paris.
<i>Certhium melanoides</i> funa- tum .....	{ Epernay, Anvert, Ba- gneux, Paris, &c.
<i>Ampullaria depressa</i> .....	

## REPTILIA.

<i>Crocodylus d'Auteuil</i> .....	Near Paris.
<i>vulgaris</i> .....	Irawadi.
<i>de Provence</i> .....	Mine de Memel (Provence).
<i>Leptorhynchus</i> .....	Irawadi.
<i>de l'Inde</i> .....	Ditto.
<i>Trionyx de l'Inde</i> .....	Ditto.
<i>Salamandra ogygia</i> , Goldf.	
<i>Triton Noachrus</i> , Goldf.	
<i>Rana diluviana</i> , Goldf.	
<i>Ophis dabius</i> , Goldf.	

## MAMMALIA

<i>Mastodon sagittatus</i> .....	Kopfnach near Zurich.
<i>elephantoides</i> .....	Irawadi.

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	Elephas .....	Kopfnach, Irawadi.
	Antilocapra .....	Irawadi.
	Anthracotherium magnum .....	Cadibona. (Tuscany.)
	minus .....	Ditto.
	minimum .....	Ditto.
	alesticum .....	Loban.
	siliatense .....	Caribari. (Bengal.)
	Lophiodon Laonnense .....	Department de l'Aisne.
	Boe .....	Irawadi.
	Castor des lignites .....	Kopfnach.

### Dislocations of the Tertiary Strata.

After the deposit of the chalk and the plastic clay strata, and after the accumulation upon it of several regular marine tertiary strata, extensive disturbances happened, by which the chalk and all the older strata were thrown into new positions, and the whole configuration of the land in the Northern zones was greatly changed.

In England, the effects of general convulsions at this epoch are very striking in the Southern Counties, and chiefly referable to two nearly parallel great undulations of the strata, of a peculiar character, ranging East and West. These undulations are of such a kind, that there are two axes of elevation and two parallel troughs. The Northern trough is nearly in the line of the Thames from London to Reading, beyond which it appears to end; the Southern trough is directed along the Solent, towards the extension of the chalk beyond Dorchester, beyond which it also appears to end. The Northern axis of elevation passes through the Weald of Kent and Sussex, South of Guilford to Highclere in Hampshire, and is continued along the Vale of Pewsey, but ends toward Devizes. The Southern ridge of strata passes through the Isles of Wight and Purbeck, and between Weymouth and Bridport, and ends at some point in the Channel before arriving at Torbay.

These great undulations appear evidently caused by violent elevation of the strata along the two lines described; and it is exceedingly remarkable that the effect of the convulsion is such, that in each case the declination of the strata on the North side is generally very steep or *even vertical*, as at Guilford on the one ridge, and in the Isles of Wight and Purbeck on the other, while on the South side the chalk in Hampshire, and the green sand and oolitic groups in the Isles of Wight and Purbeck, are nearly level or slope gently to the South.

It is further observable, that for a certain length in the middle of each axis of elevation the strata are vertical or nearly so, on the North side, but on each side of this length the inclination becomes less and less violent, and at considerable distances, in one of the ridges, is reduced to a gentle slope. Thus, on the Northern ridge, the strata are violently inclined along the line by Highclere in Hampshire, (where the chalk attains its greatest elevation in England,) and at Guilford, but both Westward toward Devizes, and Eastward toward Kent, the slopes become gentle. Also on the Southern ridge, the strata are *highly* inclined North of Weymouth, *nearly vertical* in the Isle of Purbeck, but *absolutely vertical* at the Western end of the Isle of Wight, and in Culver cliffs (Eastern end of the Isle of Wight) instead of being vertical are inclined 70° North.

From these data we may infer confidently that the disturbing force acted from below along particular lines, and most violently at certain points in these lines; and because of the unequal declinations of the strata on the

opposite sides of the ridges, we may perhaps admit the force to have been exerted in an *oblique direction*. This latter conclusion has often been suggested to us while considering the ordinary phenomena of *faults*.

### Diluvial Deposits.

We have now concluded the history of the deposits formed on the beds of the ancient sea, in its depths, along its shores and in its estuaries, and we have noticed the contemporaneous or alternating accumulations from the fresh waters which then flowed upon the Earth. The tertiary system of strata, by showing us remarkable alternations of fresh-water and marine deposits, appears to establish a connection between the ancient and the modern World, between the subaqueous and the elevated land.

The whole of that system presents us with strong analogies to the present order of things, in its races of animals and plants; and its fresh-water deposits have often a clear relation to the present level of the continents, and on this account might be viewed as the oldest of the alluvial formations.

Yet upon closer inquiry it will be found that in many cases a very strong line of distinction is drawn between the tertiary formations and the true alluvial accumulations, by the intervention of an irregular mass of deposits, evidently produced by inundations of extraordinary violence upon the face of the dried and inhabited Earth. These deposits are so extensive, and over large tracts of the Earth's surface have so much of a common character, that they have very generally been classed as the productions of one turbulent period in the process of the formation of the Globe, and termed the Diluvial deposits.

This term was first employed by Mr. Smith, and when subsequently adopted by the English School of Geology, it was often understood to refer to the effects of the Noachian Deluge; and though on this point opinions are now more unsettled and various, the term may still be very properly employed by Geologists of every School to mark the effects of turbulent inundations upon the inhabited land, happening within a particular period in the History of the Globe. In this sense we employ it.

Without entering upon the unprofitable history of the delusions in which Geologists have involved themselves on the subject of the Noachian Deluge, it will be proper to remark that all discussions of this nature are useful or injurious according as they are carried on independently of or in connection with Theology. Burnet and Woodward, by mixing up false hypotheses with Scriptural History, retarded the progress of Geological Science, and sanctioned a perverse application of the Mosaic narrative to support every new, fanciful, and unsubstantial theory.

We must always bear in mind that it does not follow that all deluges must be referred to the Noachian flood; certainly many turbulent waves have traversed the Globe before the creation of man; some local deluges have happened since the days of Noah. It may therefore very possibly be true that the turbulent waters of which we are now to trace the effects upon the surface of the Earth, may be quite independent of the Deluge of Scripture; we have no right to *assume* any connection between them; and at all events it will be prudent before thus entangling ourselves in fetters which it may be difficult to unclasp, to wait for a full investigation of the subject. Many curious questions of time and circumstance are involved in such a comparison which it will be wise to reconsider.

There is nothing in Geology less improbable than the

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occurrence of a period of violent watery action, for in the course of our survey of the stratified rocks, we perceived clearly that, during their production, long periods of regular and ordinary action have been frequently succeeded by temporary disturbance. The epochs of these disturbances relatively to other phenomena are precisely assignable. They differ in importance, and while some are so great and extensive as to afford means of classifying the strata over large surfaces of the Globe, others seem to have happened locally and irregularly.

The present system of Nature may be considered as one of the periods of regular action, and the effects now produced upon the land and in the sea are of the same kind as those occasioned during the comparatively tranquil periods of older nature, because upon the whole the levels of sea and land are constant. But the deposits called diluvial are characteristic of a period of watery tumult and disturbance of the most extensive kind, and are to be associated mentally with other great epochs of disturbance which mark temporary convulsions in the ancient system of Nature. This watery tumult differs, however, from all anterior deluges, by the circumstance that we are looking upon the land and reading there the traces left by violent waves, while those of ancient times are known to us only by the effects they produced in the sea.

**Proofs**  
We shall now present the proofs of such a system of turbulent waters having passed over large portions of the surface of the inhabited Earth, since the formation of all or nearly all of the stratified rocks now visible above the Ocean, and since the present continents were dried, elevated, and inhabited.

**Diluvial is the name of the**  
**Cumbrian mountains.**  
1 Without venturing to assert that every region of the Earth's surface is covered by the water-moved ruins of rocks, and waste of distant mountains, in situations to which existing streams could not carry them, we may state that observations of this nature are general for all parts of the Continent of Europe, Northern Asia, and Northern America, Countries which have been, better than any other, explored by Geologists. In all these regions, great deposits of gravel, sand, and clay, containing in more or less abundance portions of all the known rocks and strata, lie spread over formations of every age, primary, secondary, and tertiary. There is no order in the arrangement of these heterogeneous materials, no constant series or succession of deposits, but the utmost confusion and irregularity. The materials lie sometimes in valleys, often on hills, crossing in their course both hills and valleys, and appearing to have little relation to the track of the existing streams, though sometimes evidently influenced by the great physical features of the districts. Though the subject of the direction of diluvial currents, with reference to local geography, has not been sufficiently attended to, even in England, we are able to bring forward some striking instances in support of the preceding statements. It is well known that the mountain group of Cumbria encloses remarkable kinds of granite, sienite, and other rocks, and that they are separated from the Eastern parts of the Island by a long unbroken range of carboniferous limestone stretching from the Tyne to the Aire. A considerable hollow every where divides these ranges; and in some parts, as in the vale of Eden, the hollow is from 1000 to 2000 feet, or more, below the summits on either hand. The lowest point in the whole line of carboniferous limestone, which offers itself directly to the West, is at Stanmore, about 1000 feet above the sea. Now by the force of the currents of water alluded to, blocks of the

curious porphyritic granite of Shap Fells, have been removed from their original sites, (1500 feet above the sea,) swept over a ridge of limestone rocks about Craven, into the red sandstone vale of Eden, and from this deep and ancient vale lifted up the steep of Stanmore to the very summits of the pass. From thence they have been urged forward as from a new centre, and spread in a radiating manner over the South of Durham, and the whole extent of the vales of York and Cleveland, to the foot of the Hambleton Hills and the Wolds. Against these great barriers, considerable quantities of the rocks of Cumberland, and likewise of the carboniferous system of Yorkshire, are collected, but a large portion of the debris has also travelled over and beyond parts of these high districts and reached the sea side, where many of the cliffs are covered by blocks swept from Cumberland and North Western Yorkshire. In passing from Shap Fells to Holderness, the granitic boulders have been transported across two deep vales, and over two elevated ranges of hills. In passing over these hills, we clearly perceive that the blocks were wafted by the easiest ascents. This is remarkably the case at Stanmore, the lowest point in the long carboniferous summit, and the only one crossed by the diluvial boulders. It is therefore evident that at the period when these violent waters flowed over the North of England, the land had assumed its present general shape and altitude, it is also clear that the floods were influenced in their direction by the great physical features of the country, but that at particular points they were of force and volume enough to overcome those natural obstacles.

Besides the porphyritic granite of Shap other remarkable rocks of the Eastern part of the Cumbrian mountains have followed the same course. The hypersthene and sienitic rocks of Carrock Fell, the brecciated and amygdaloidal slates of Grasmere, Ulswater, &c may be often recognised in the same situations. Perhaps the most instructive of all examples derived from this country is that furnished by the red 'brockiam' of Kirby Stephen. This member of the saliferous formation is easily known by its fragments of carboniferous limestone imbedded in red sandstone, and its native site is in the depth of the vale of the Eden. From this deep repository it has been lifted by the diluvial currents over Stanmore, and thence carried with the granites and other rocks of the Cumbrian group.

The currents to which these effects are ascribed, must have flowed from the North-West. From the Western part of the Cumbrian group of mountains, currents flowing nearly from North to South have carried the granite of Ravenglass and Muncaster along the low ground West of the carboniferous chain of Yorkshire and Lancashire to the vicinity of Manchester, and through a great part of Staffordshire, but this sort of granite has no where crossed the carboniferous chain, to spread down the valleys of the Aire, Dun, Derwent, or Dove. In this case, as in the former, it is evident that the current was directed by the great physical features of the country, which were the same then as now.

The quartz pebbles of the Lurkey have been widely diffused over the plains of Warwickshire and Gloucestershire to the foot of the Cotswold Hills, but on arriving at this barrier they are stopped, except at two low points, the summits of the valleys of the Cherwell and the Evenlode. Down these valleys, and along their borders, the pebbles hold separate courses till the streams unite near Oxford, after which the general course of the

**Lurkey Hill.**



From the Alps. valley of the Thames is the line of the diluvial deposits.

A tendency to be arranged in narrow, longitudinal spaces is sometimes observable in the diluvial accumulations. In Lincolnshire a long narrow ridge of diluvial chalk runs out in a South-Westward direction by Faldingworth. In Yorkshire the lias boulders from Robinhood's Bay keep nearly parallel to the present North and South line of coast; and the flinty gravel from the Wolds runs North and South from Pocklington to Cave. These observations will probably be much extended hereafter.

From the Alps.

The most extraordinary effects of tumultuous waters upon the surface of the land, appear sometimes to surround lofty ranges and groups of mountains. Thus the Mont Blanc group of primary mountains has been rent to pieces by some violent convulsion, and its mingled fragments transported along the *lines* rather than in the actual channels of the Rhone and the Arve into the Valais, along the Lake of Geneva, and up the slopes and through the valleys of the Jura even far into France. By this extraordinary course, blocks of enormous magnitude have been drifted in great numbers on to the tops of mountains, even to the height of 2000 or 3000 feet above the Lake of Geneva, and left there in such abundance as to encumber the land with thousands of extraneous masses. There appears in these collections of blocks a very singular tendency to association in groups and lines. (De Luc.) It is particularly to be remarked that no ordinary action whatever could possibly cover the abrupt mountains of the Saleve and Mont Sion with such immense and numerous masses of these rocks, or transport them across the deep and wide valley of the Rhone to the steep slopes of the Jura. For such powerful effects it will be difficult to assign an adequate cause, and however much influence we may ascribe to the impetuosity even of an uplifted sea possibly cooperating with the disruption of glacier-covered mountains, the phenomenon must ever appear of the most remarkable kind.

We seem to perceive, on a general view of the dispersion of these *erratic blocks* from the Alps, a remarkable relation to the existing valleys. While the Mont Blanc group have yielded fragments to the Rhone and the Arve, the Bernese oberland has supplied the basin of the Aar and the neighbouring part of the Jura; the valley of the Reuss has conveyed the waste of the mountains at its source; blocks from Glaris lie by the Lake of Zurich, and the valley of the Rhine holds the rocks of the Grisons.

The great range of the Jura, opposed to the Alps, and separated from them by the long and wide valley of the Aar prolonged into the Lake of Geneva, has furnished the best opportunity of determining the geographical and other data belonging to the curious problem of the dispersion of these blocks. It is certain that in their course from the Alps the blocks have principally followed the line of the present valleys, since they are found along their sides in greatest plenty, and are collected in most abundance, and lie at the greatest heights, on those parts of the Jura chain which directly face the embouchures of the valleys. Yet this relation to the valleys is of such a kind, that the blocks, instead of being limited to their beds, lie perhaps more plentifully on the hill sides, and intimate a totally different kind of watery action from that of the running streams. Some general convulsions under water, at once elevating the mountains and opening the valleys, and pouring along the floods, may safely be considered to have caused the phenomena.

One of the grandest examples of the form and direction of diluvial currents is the dispersion to the Northward, across the Baltic, of the primary and transition rocks of Sweden and Norway. Wedegast (Tidens des Terrains) has given an excellent view of these phenomena.

The sandy plains of Westphalia, Hanover, Holstein, From Scap Zeeland, Mecklenburg, Brandenburg, the coasts and dinavia plains of Pomerania, Prussia, and part of Poland far inland between Warsaw and Grodno, and consequently all the low, generally flat, and sandy Countries which border the Baltic and the German Ocean from the Elbe and the Weser to the Dwina, and even the Neva, are covered at intervals by these blocks. They are not uniformly dispersed, but collected in particular spaces, and form in the midst of these vast sandy wastes distinct groups, generally elliptical in outline, with the longer axis directed North and South, or toward the Baltic Sea. Bruckner mentions a *trainée* of these blocks in the Northern part of Mecklenburg-Strelitz, which runs from West North-West to East South-East. They are more abundant on hills than in valleys. The largest blocks are most superficial and nearest the tops of the hills. They consist of granites, sienites, transition limestone with trilobites, &c., and other rocks which have the greatest resemblance to the rocks of Sweden; they contain the same *peculiar* minerals, and the same *peculiar* organic remains. Their course from the Scandinavian peninsula is generally from North-East to South-West. On approaching the mountains whence they were dislodged, we find the number of the blocks to increase considerably, and on crossing the Sound to Scania, they appear at every step, but the size of the blocks is not greater. The mountains of Sweden are not more burdened by loose blocks than is common to such tracts, but the faces of the rocks there appear furrowed and rubbed by the drifting of heavy bodies. The Baltic Sea, which crosses the line of these *trainées* of rocks, appears to have interposed no obstacle to their movement, since the heaps of blocks lie in the same direction on both sides of the water, and the quantities carried over are immense.

Many of the granitic boulders on the coasts of Yorkshire and Norfolk are thought to have come from the same Scandinavian mountains. From observations in England, Dr. Buckland inferred that the general direction of the diluvial currents was from the North-West. In North America, Dr. Bigsby and other observers have observed the prevalent direction to be from the North-West or North-East; the Scandinavian blocks have travelled also from North-East or North North-East. But the waste of the Alps has gone nearly as the valleys run, in all directions; Southward to Italy, Westward to France, Northward to the Rhine, and generally we may be assured that the prevalent direction in any Country has a very close relation to the physical geography of the region.

The degree of attrition of the erratic blocks is various, and generally not so considerable as that of the smaller pebbles which compose the greater part of the diluvial masses.

From the preceding data we are warranted in concluding that since the deposition of all or nearly all the marine strata which are seen in our continents, and since the actual land was uplifted from the sea and shaped into its present leading physical features, large parts of the Earth's surface have been denuded by floods. Inference.

pointing in various directions, which transported large quantities of the preconsolidated rocks, and dispersed them over distant Countries, in such abundance, of such magnitude, in such distances, in such directions, and to such altitudes, as to preclude the possibility of explaining the phenomenon by the action of *actual streams*, flowing in the ordinary course of nature, or deviating in any possible manner over the surface of the Earth, or by the bursting of lakes, however situated or circumstanced. For neither streams nor bursting lakes could possibly transport the Shap Fell granite to Flamborough Head, nor drive the sienites of Sweden into the heart of Poland.

Gravel deposits.

For the sake of exhibiting decided proofs of the powerful action of the diluvial waters, we have insisted much on the transport of large blocks of recognisable rocks; but it must not be imagined that such blocks of such magnitude compose the whole or the greater part of the diluvial deposits. These consist, in fact, of the detritus and fragments of every sort of rock, and of all sizes, from the giant blocks on the Jura to the finest sand and sediment. The Eastern coasts of England, in Essex, Norfolk, and Yorkshire, are principally occupied by diluvial cliffs of clay, with interspersed pebbles and blocks, and irregular layers of gravel and sand. These deposits cover large tracts in Yorkshire, Lincolnshire, Norfolk, Suffolk, Essex, &c. In the Midland Counties, gravel, containing in some places abundance of chalk flints, and in other situations pebbles from the Lickey Hill, is very common, and particular valleys quantities of oolitic gravel. It is generally observable that the most abundant portions of the deposits may be traced to the neighbouring ranges of hills, as the chalk of Holderness, Faldingworth, and Huntingdon, to the neighbouring wolds, the sandstones of the vale of York to the Western moorlands, and the quartz pebbles of Warwickshire to the Lickey Hill, but with them generally lie fragments from more distant sources.

Animal population at the time,

We now proceed to inquire what was the condition of the land over which the diluvial currents flowed, with respect to its animal population. That it was inhabited, and very extensively so, in many districts wasted by these floods, is evident from the really immense quantity and variety of bones of quadrupeds lying in gravel pits, clay cliffs, and other diluvial accumulations, or buried in caverns during and previous to that period of convulsion.

To mention all the known localities for diluvial masses from which bones of elephant, rhinoceros, horse, ox, deer, and a variety of other quadrupeds have been obtained, would be to form a gazetteer of Europe, Siberia, and North America. There is hardly a County in England where some remains of this kind have not been obtained at many places, and they are equally abundant in France, Germany, Italy, &c.

Exactly as at the present day the bed of a river envelopes the shells that perish in its waters, with the bones of animals accidentally lodged there, so the diluvial floods buried in the detritus of the land remains of the then existing organized creation. These remains enable us to say what races of animals were living upon the Earth at and previous to the time when those parts of it were overwhelmed; and if upon examination, it be found that these animals were of peculiar types of conformation, that they did not begin to exist till a certain epoch, nor continue to live after another epoch, the period of their existence is a geological era as distinct as any other disclosed to us by examination into the

long series of periods during which organic beings have existed upon the Earth.

In illustrating this magnificent subject from the materials furnished by the researches of Cuvier and Buckland, we shall first present the evidence furnished by diluvial gravel, clay, sand, and other unquestionable deposits of the turbulent era alluded to; and afterwards add some results deducible from examination of caverns, the period of the occupation of which will be naturally determined by comparing their zoological contents with those of gravel pits, &c.

The following are some of the animals that have been discovered in these diluvial deposits

#### *Pachydermata*

<i>Elephas primigenius.</i>	<i>Rhinoceros tichorhinus, &amp;c.</i>
<i>Mastodon maximus, &amp;c.</i>	<i>Tapir giganteus.</i>
<i>Hippopotamus major.</i>	<i>Sus fossilis.</i>
<i>Choropotamus.</i>	

#### *Solipeda.*

*Equus fossilis.*

#### *Ruminantia*

<i>Cervus euryceros, &amp;c.</i>	<i>Urus.</i>
<i>Bos.</i>	<i>Merycotherium Sibericum.</i>

#### *Carnivora.*

<i>Felis spelæa, &amp;c.</i>	<i>Vulpes speluncarum.</i>
<i>Hyæna spelæa, &amp;c.</i>	<i>Ursus cultridens.</i>
<i>Wolf.</i>	<i>spelæus.</i>

#### *Rodentia.*

<i>Porcupine.</i>	<i>Arvicola.</i>
<i>Beaver.</i>	

#### *Edentata.*

<i>Megalonyx.</i>	<i>Manis giganteus.</i>
<i>Megatherium, two species.</i>	

The most striking general inference derivable from inspection of the preceding and more extended lists, as contrasted with all the catalogues of the earlier animals, is the almost complete identity of the genera with some of those which now exist. Even in the tertiary system, though the quadrupedal population of Europe had become considerable, and the circumstances of their existence in several respects closely analogous to what obtain at present, the genera were for the most part wholly different. Here they are for the most part the same.

The species, however, of the zoological era under consideration were mostly different from the existing races, some of greater magnitude, others of different proportions, all distinguishable by more or less remarkable peculiarities of their bony remains. Yet these distinctions are often minute, and unless the question of the amount of possible change induced on the apimal frame by long time and varying circumstances could be more exactly appreciated, it may perhaps always admit of a slight doubt whether the distinctions alluded to be characteristic of the species of animals, or of the circumstances of their existence. However, for all purposes of geological induction, the distinctions being constant are assumed to be specific.

Among the species found in caves, fissures, and breccia, referred to the same era, are the following.

#### *Pachydermata.*

<i>Elephas primigenius, &amp;c.</i>	<i>Choropotamus.</i>
<i>Hippopotamus major.</i>	<i>Sus fossilis.</i>
<i>Rhinoceros tichorhinus, &amp;c.</i>	



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Ch. II.*Solipeda.**Equus fossilis.**Ruminantia.**Cervus euryceros, &c.**Bos, urus, antelope.**Carnivora.**Felis spelæa, &c.**Wolf.**Hyæna spelæa, &c.**Fox.**Polecat.**Ursus spelæus.**Weasel.**cultridens, &c.**Gulo spelæus.**Rodentia.**Arvicola fossilis media.  
minor.**Lagomys, &c.**Hare, rabbit, &c.**Rat.**Beaver.*

From the general analogy between these two lists, from the prevalence in each of elephants, rhinoceros, hippopotamus, felis, hyæna, and bears, in Countries where at present not a single animal of such genera is known to exist, there seems every good reason to admit them as belonging to the same zoological era, which M. Omalius D'Halloy has, not inconveniently, called the mastozoötic era. But all investigations concerning gravel and other diluvial deposits, prove indubitably that this era is exactly that which ended with the diluvial system of deposits. We may, therefore, venture in the following investigations to class together the remains of mammalia found in caves, fissures, breccia, gravel, clay, &c. as characteristic of a period of some duration, terminated in each district by great inundations, and equally capable of furnishing evidence concerning the then state of the Earth. It is not meant by this arrangement to pronounce at all concerning the question yet very insufficiently examined, of the partial contemporaneity of the palæotherian and mastozoötic races of animals in Europe.

Lived in  
Countries  
where their  
bones are  
found.

The first general result which we shall venture to draw from this combined evidence is, that the animals whose remains are found in diluvial gravel and other superficial accumulations, or in limestone caves and fissures, or in ferruginous breccia, lived near or on the spots where their bones are found. This important inference might be safely deduced from the ordinary circumstances under which fossil bones are found in superficial gravel, &c., since in these cases they are little worn, though lying amongst fragments of rocks rounded to pebbles, and often remain entire, or with no other injury than that occasioned by the effects of the atmosphere. Thus, the horns of a stag, scarcely in the smallest degree injured, have been obtained from the diluvium of the vale of Pickering, the long tusks of an elephant from that of Holderness and Essex. This conclusion might, perhaps with equal certainty, be rested upon the occasional finding of the bones of elephants and rhinoceros, and other "antediluvian" species, in marl pits under gravel, in company with shells now existing in the neighbourhood, of which some indications occur in Cuvier's celebrated Work the *Ossements Fossiles*, and a more distinct case, at Market Weighton in Yorkshire, has been recorded by Mr. Dikes of Hull, and several members of the Yorkshire Philosophical Society. For in this case the bones of extinct and the shells of existing species of animals lay pellmell together, and the native locality of one must inevitably be ascribed to the other.

But the case becomes certainly stronger, when we

take into view the history of the caverns, fissures, and breccia, containing bones; for these afford us not only reason to conclude that certain animals lived in definite regions at a particular era, but display many of their habits of life and accidents to which the nature of the country exposed them. Those who desire to follow at length the detailed history of caves and osseous breccia must be referred to the luminous pages of Buckland, (*Reliquiæ Diluvianæ*;) and that imperishable monument of genius, the *Ossements Fossiles* of Cuvier. We shall here present a simple analysis of the leading results of their inquiries bearing on the subject before us.

Caverns and fissures containing bones, however preserved, and of whatever kinds these are, present some important characters in common.

(1.) In the first place they are, we believe, always situated in limestone, very generally in stratified limestone, though this character is sometimes denied to the dolomitic limestone of the Mediterranean shores. This circumstance has, however, apparently no relation whatever to the accident of the caves containing bones, but is merely a general fact characteristic of limestone; for in this kind of rock nearly all the caverns, grottoes, and remarkable natural fissures in the World are situated. And as far as we have observed, there is no reason whatever in speculations on the origin of the bone caverns and fissures to exclude those of similar forms in which no bones occur.

Ossiferous  
caverns,  
how situated.

(2.) This being the case, we may remark further, that though in some cases the existence of the cavern may be thought to be connected with dislocations of the strata, as at Greenhow Hill in Yorkshire, yet this is rather the rare exception than the general rule. The carboniferous limestone is full of caverns, yet not more so where numerous slips and veins divide it than in other places. Veins of lead ore hardly ever lead to these caverns, and it is a matter of general remark, that though the strata may be disturbed near them, the disturbance has little to do with the caverns.

(3.) Most caverns, whatever be the character of their floor, assume at intervals along their length, the appearances of a great fissure in the rocks. This circumstance must have been often observed by those familiar with the caves of Somersetshire, Derbyshire, and Yorkshire, and is recognised even in that least favourable example, Kirkdale Cave, which in its nearly level course keeps its floor nearly on one particular bed of the rock, but occasionally opens upwards into narrow irregular expansions or fissures. The fissures filled with breccia may, in fact, be often regarded as exposed caves, and resemble them in all essential circumstances.

(4.) Very few of these cavities in the rocks are naturally free on their sides and roof from remarkable depressions and cavities, like those produced on limestone by currents of water, or the slow consuming agency of the atmosphere. Many of them which now convey water, and are not incrustated with stalagmite, as the Peak Cavern in Derbyshire, show this sort of watery erosion so strongly as to impress most beholders with a conviction that the whole was excavated by the running stream.

(5.) Several writers, in particular Brongniart, have attempted to show that mere water has no effect in eroding rocks. This may, perhaps, be true of the oxide of hydrogen, but is certainly not a correct account of the effect of common water, and particularly of water containing carbonic acid, and traversing limestone rocks. The innumerable petrifying springs of limestone Coun-

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tries at once demonstrate the inaccuracy of this reasoning. The very rain from the heavens eats away these stones rapidly. The springs which issue from limestone generally contain carbonate of lime, and most of them yield a large quantity of free carbonic acid upon exposure to the air.

How formed.

(6.) Those accustomed to underground works know it as a familiar fact, that the water which is absorbed by dry limestone land, takes particular channels through the rocks, down the joints, and along certain fissures. Every limestone hill in the carboniferous district of the North of England, shows in its *swallows* and *moor pits* the erosive power of the atmospheric water. We shall, therefore, venture from all these considerations to maintain the enlargement or excavation of these caverns to be principally owing to the subterranean passage of water charged with carbonic acid, the direction of this water, and its power of erosion, being favoured by fissures and other causes. If the altered drainage and other circumstances of a country so far change the course of the water as to leave these subterranean channels almost dry, the small quantity of moisture continuing to arrive, may slowly deposit stalagmite over the surfaces formerly eroded, and the cave change its appearance altogether. An accidental inrush of water from another source may deposit mud or pebbles, and this be also covered up by another layer of stalagmite.

It is no great objection to this view, that the cavities are sometimes exceedingly irregular, for water in its subterranean course must follow the original cracks of the rocks. Indeed, upon a review of this matter, that very irregularity may perhaps be thought an argument in favour of the mode of origin here suggested.

The most remarkable ossiferous caverns in England are Kirkdale Cave near Kirby Moorside in Yorkshire, the Dream cavern near Wicksorth in Derbyshire, Banwell Cave in the Mendip Hills, Kent's Hole near Torquay, Oreston near Plymouth, and Paviland near Swansea; in Germany, the slopes of the Harz mountains give us the caves of Baumbach, of Biel, and of Schwarzfeld. Between the Harz and Franconia is the Bear Cavern of Glücksbrunn; the Jura formation near Barenth is celebrated for the rich associated caverns of Gadenreuth, Schenestein, Brunnenstem, Hölberg, Wieserloch, Geissloch, Wunderhohle, Rubenstein, Kubloch, Zahnloch, Schneiderloch, Rewig, &c. In Westphalia the same oolitic formation has the caves of Kluterhohle, and Sundwich. The Caves of Adelsburg in Carniola and the Dragons' Caves in Hungary have also yielded bones. In France, instructed by Dr Buckland's researches, two caverns, rich with bones, have been described by M. Thirria near Vesoul, and several others near Montpellier and Narbonne by Marcel de Serres, Tournai, Christol, &c. and one near Miremont by M. de la Noue.

Osseous breccia appears singularly connected with the coasts of the Mediterranean. It occurs at Gibraltar, in Languedoc, and at several other points in the South of France, at Antibes, Nice, Pisa, Cape Palmaris, North of Bastia, (Corsica,) Cagliari, (Sardinia,) Maridolce, (Sicily,) in Dalmatia, Aragon, &c. Ferruginous breccia, in which bones are associated with pisolitic iron ore, occurs in Wurtemberg, and in Carniola in Jura limestone.

How filled with bones.

In some of these caves hyænas lived and dragged into them for food the bones of other animals existing in the vicinity; bears died in others; some were filled by the accidental falling in of browsing quadrupeds, and others heaped with a mixture of bones, mud, and pebbles brought by general or local floods on the surface.

We shall give an abstract of the characteristic facts attending each of these cases.

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Kirkdale Cave.

Kirkdale Cave is one of the most remarkable instances of ossiferous cavities known in England, both from the number of species and abundance of the bones of quadrupeds found there, their state of conservation, and other attendant circumstances. The entrance of this cave is on the side of a narrow valley 30 feet above the stream in a nearly level and perfectly undisturbed bed of coralline oolite. It had a sort of vestibule, much larger than the interior windings of the cave, and in this, according to Mr. Salmond, lay a considerable proportion of the large bones of elephant, rhinoceros, &c. Beyond this was a step in the floor of the thickness of one bed of limestone, leading to the interior recesses, which follow an irregular line, occasionally rising to the height of 14 feet, but generally under 4 feet, and about the same breadth, but liable to contractions in both their measures. The floor was generally overspread and its inequalities filled up by a layer of mud, of calcareo-argillaceous substance, such as might be supposed derivable from the joints and partings of the limestone. In some places the mud was more coarse and sandy. Stalagmite in considerable quantity had dripped from the roof, incrusting the sides, and covered like a sheet the layer of mud rising upon its surface into mamillary tubercles.

In the mud, and protruding occasionally through its stalagmitic covering, lay the bones of six or seven *canivora*, hyæna, tiger, or lion, bear, wolf, fox, and weasel; three *pachydermata*, viz. elephant, rhinoceros, hippopotamus, the horse; four *ruminantia*, ox, and three kinds of deer; four *rodentia*, hare, rabbit, water rat, mouse; beside five birds, raven, pigeon, lark, duck, and a bird of the size of a thrush.

The bones were scattered over this long area, "as over a dog kennel," almost universally broken to pieces, not as if by common fracture, but by violent biting and gnawing; marks of teeth are discernible on many, exactly like those left by living hyænas on similar bones submitted to their jaws. Hyænas' teeth in great numbers, of all ages, milk teeth, shed teeth, and worn to stumps in the jaws of the animal, abounded in the cave, besides a considerable quantity of osseous fecal matter, like that of the modern hyæna. From these data, most of which may be verified on the numerous specimens extracted from the cave, Dr. Buckland infers, that hyænas were for a long period the undisputed tenants of this den, lived in it for many generations, dragged into it for food, piecemeal, the bodies of animals then living in the neighbourhood, and were finally dispossessed of their hold by an irruption of water which let fall the muddy sediment now enveloping the bones. The ordinary action of the water passing through the calcareous rock then covered the whole with stalagmite, and closed up the bones from the destructive agency of moisture and air. This accounts for the conservation of their gelatine. Few conclusions of this precise nature appear better supported by the facts of the case, and when we reflect on the remarkable analogy, in almost all points concerning the state and conservation of the bones, of the cavern at Torquay called Kent's Hole, and contrast these particulars of the *hyæna dens* with those of the *or caves* in Mendip, we shall feel a full conviction that Dr. Buckland's bold theory is a true interpretation of Nature.

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Kühloch.

The caves of Franconia appeared to Dr. Buckland to have been tenanted by bears which died in the retired parts, and were there mixed more or less with sediment and pebbles brought by subsequent diluvial floods, and the whole covered over by a stalagmitic crust formed in the usual way. The cavern of Gailenreuth is perhaps the most magnificent example of this doctrine; but that at Kühloch presents some peculiarities of a very interesting kind. "It is literally true that in this single cavern (the size and proportions of which are nearly equal to the interior of a large church) there are hundreds of cart-loads of black animal dust entirely covering the whole floor, to a depth which must average at least six feet, and which, if we multiply this depth by the length and breadth of the cavern, will be found to exceed 5000 cubic feet. The whole of this mass has been again and again dug over in search of teeth and bones which it still contains abundantly, though in broken fragments. The state of these is very different from that of the bones we find in any other caverns, being of a black or more properly speaking dark amber colour throughout, and many of them readily crumbling under the finger into a soft dark powder resembling mummy powder, and being of the same nature with the black earth in which they are imbedded. "The quantity of animal earth accumulated on this floor," continues Dr. Buckland, "is the most surprising and the only thing of the kind I ever witnessed; and many hundred, I may say thousand individuals must have contributed their remains to make up this appalling mass of death. It seems in great part to be derived from comminuted and pulverized bones; for the fleshy parts of animals produce by decomposition so small a quantity of permanent earthy residuum, that we must seek for the origin of this mass principally in decayed bones. The cave is so dry that the black earth lies in the state of loose powder and rises in dust under the feet: it also retains so large a proportion of its original animal matter, that it is occasionally used by the peasants as an enriching manure for the adjacent meadows." This cave is entered by a lofty arch, above the river Erbach, expands within both in height and breadth, and terminates in two chambers closed at the end. No fissures enter this cave, and it has no other exit than the entrance above named, except a very small passage to the same valley. These circumstances are considered by Dr. Buckland to explain the absence of diluvial accumulations in this cave. There is no appearance of either stalagmite or stalactite having ever existed in this cavern.

Mendip  
caves.

Dr. Buckland's views concerning the ancient occupation of hyænas and bears of the caves of Kirkdale and Franconia, derive much elucidation from the discoveries of other caverns in which the animal remains appear to have been accumulated in a different manner. We shall mention those of Hutton in the Mendip Hills, and of Ouston near Plymouth; the former disclosed by ochre works, the latter by quarrying for limestone. The ochre of Mendip Hills appears, in some cases, to be derived from the decomposed strata of the vicinity, and deposited in caves and fissures of the limestone, either by water continually passing downwards by filtration, or by some more transient and violent operation. In pursuing one of these mines of ochre near the village of Hutton, bones of many animals were discovered, and the circumstances were examined by the Rev. Mr. Cutcott, from whose manuscript Mr. Conybeare has

drawn up a clear account of this remarkable occurrence. The elevation of the ochre pit was 300 to 400 feet above the sea. "The ochre was pursued through fissures in the limestone occasionally expanding into large cavernous chambers, their range being in a steep descent and almost perpendicular. In opening the pits the workmen, after removing 18 inches of vegetable mould and 4 feet of rubbly ochre, came to a fissure in the limestone rock, about 18 inches broad and 4 feet long. This was filled with good ochre, but contained no bones: it continued to the depth of 8 yards, and then opened into a cavern about 20 feet square and 4 high; the floor of this cave consisted of good ochre, strewed on the surface of which were multitudes of white bones, which were also found dispersed through the interior of the ochreous mass. In the centre of this chamber a large stalagmite was suspended from the roof, and beneath a similar mass rose from the floor almost touching it; in one of the side walls was an opening about 3 feet square, which conducted, through a passage 18 yards in length, to a second cavern 10 yards in length and 5 in breadth, both the passage and cavern being filled with ochre and bones. Another passage, about 6 feet square, branched off laterally from this chamber about 4 yards below its entrance; this continued nearly on the same level for 18 yards; it was filled by rubbly ochre, fragments of limestone, and lead ore confusedly mixed together; many large bones occurring in the mass, among which four magnificent teeth of an elephant were found. In the second chamber, immediately beyond the entrance of the branch just described, there appeared a large deep opening, tending perpendicularly downwards, filled with the same congeries of rubble, ochre, bones, &c.: this was cleared to the depth of 5 yards; this point being the deepest part of the workings was estimated at about 36 yards beneath the surface of the hill." (*Reliq. Diluv.*) The bones found in Hutton Hole belong to elephant, rhinoceros, ox, horse, deer, hyæna, bear, a nearly complete skeleton of a fox, hog, and some gnawing animal.

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Three deposits of bones at Ouston, near Plymouth, have been detected by Mr. Whidby during the removal of the entire mass of a hill of transition limestone for the construction of the Brehkwater. The first deposit (1817) lay in a cavern 15 feet wide, 12 high, and 45 long, and about 4 feet above high-water mark. This cavern was filled with solid clay, in which teeth and bones of rhinoceros were embedded. The second discovery (1820) was of a smaller cavern, distant 120 yards from the former, one foot high, 18 wide, and 20 long, and 8 feet above high-water mark. But the greatest extent of subterranean cavities was exposed in 1822, by the intersection of apertures in the middle of the limestone, containing an immense deposit of bones and teeth imbedded in clay. Dr. Buckland describes in a very graphic manner the irregular branching or insulated fissures and caverns which were at this time laid open in an artificial cliff 90 feet high, their various direction, loamy contents, and relation to similar cavities not containing bones in the neighbouring limestone cliffs. He remarks that the fissures and caverns are so connected, so often confluent and inoculating with each other, and so identical in their contents, that there appears to be no difference as to the time and manner in which they were filled. In many of those which are nearly vertical, the communication is obvious, but those which pass obliquely, and consequently seldom lie in

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Caves.

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the plane of the cliff, may appear to close upwards.\* In almost all the cavities there occurs a deposit of mud and sand, and angular fragments of limestone; these substances sometimes entirely fill up the lower chambers, and are lodged in various proportions on the shelves and ledges and in lateral hollows of the middle and upper regions. In one large vault it is sorted into laminae; sometimes it is interspersed with extraneous fragments of quartz and clay slake; stalagmite sometimes invests it; in some few spots were balls of iron-stone, and concretions of ochre formed in the clay; in others was a considerable quantity of manganese ore, sometimes in concentrically coated balls. The bones collected in the Oreston caverns and fissures belong to hyæna, tiger, wolf, fox, horse, ox, deer. The bones of the horse predominated; those of ox and deer were also abundant.

We may admit, without hesitation, that these caverns and fissures at Oreston were filled with this mingled mass of earthy, stony, bony, and metallic matters, by aqueous action; and there seems no good reason to doubt that partly in this manner, and partly by the accidental falling of quadrupeds into open fissures of the limestone, many other caves in Somersetshire, Derbyshire, &c. have been stored with their animal remains.

From such cavernous fissures, filled with mingled fragmentary masses, as those of Oreston, there is hardly a step to the fissures or caves containing ossiferous breccia at so many points around the Mediterranean Sea. Almost every limestone rock, wherever its interior structure can be seen on the sea coast, in ravines, in mines, is found to be traversed by fissures and excavated in caverns: it was therefore to be expected that such should be exposed in abundance in the calcareous precipices of the Northern shore of the Mediterranean. But it is very remarkable that they should be in those regions so generally productive of bones; that these should so generally be found in a reddish-coloured loamy breccia, holding fragments of the neighbouring rock, helices, and other spoils of the land; and that no marine production whatever should be found mingled with the mass, though, as at Santo Ciro, near Palermo, (*Geological Proceedings*, 1833,) there be proofs of the marine submersion of the actual cave, before the introduction of the bony breccia. There is clearly no necessary relation between the existence of these ossiferous cavities and the proximity of the sea; in many cases their exposure may be owing to the waste of the coast, but in others it must be mainly ascribed to the convulsive elevation of the land at some ancient period. In all cases the production of caverns and fissures in the rocks is the work of causes acting during periods long anterior to those when the animal remains were introduced. Thousands of cavities have been produced in the rocks, and filled with mineral treasures, and buried beneath vast depths of consolidated strata, of very high antiquity; such of them as were by any causes exposed at the surface, have been filled with clay, or heaped with fragments of rock, and in the great majority of instances lined with calcareous spar, and in Countries which were then inhabited by quadrupeds some have been partly filled by bones. The Geological era, when the latter occurrence happened, is rendered definite only by a rigid anatomical examination of the bones; and by this Cuvier has taught us that we may confidently refer the great majority of the quadrupedal remains, whether found in gravel on the surface, in the mud, gravel, breccia, or stalagmite, or on the naked floor of subterranean caverns, to one zoological period.

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In general, the most abundant remains in the ossiferous breccia of the Mediterranean shores belong to the orders ruminantia and rodentia; bones of ursine, feline, and canine animals, as well as those of hippopotamus and elephant, are rare. This is exactly what should happen upon the supposition that the bones in the fissures were derived chiefly from animals which fell into them, for these naturally should consist principally of herbivorous tribes. The presence of land shells, of fragments of the neighbouring rocks, the abundant interlacement of stalagmitical carbonate of lime, tends exactly to the same conclusion; and even the redness of the breccia of Gibraltar, Certe, &c., is probably owing to the ferruginous nature of the neighbouring rocks. The influence of local causes is thus clearly indicated, and in the opinion of Cuvier, these have operated through considerable periods, so that the bones and fragments of rocks fell successively into the cavity, and the calcareous cement was gradually accumulated. If, in addition, we suppose, with Dr. Buckland, that these same cavities have since undergone the action of moving water, which might drift in heaps the fragmented bones and stones, and mix with them loam and occasionally pebbles, all the phenomena seem naturally explained, and the theory of the ossiferous breccia becomes connected with that of the proper cavern deposits. For particulars respecting the ossiferous breccia of Gibraltar, Certe, Antibes, Nice, Pisa, Cape Palmurus, Corsica, Sardinia, Sicily, Dalmatia, Cerigo, Aragon, and the Veronese, we must refer to Cuvier's admirable *Ossimens Fossiles*, tom. iv.

As from the facts previously related, no doubt whatever can remain that in the "diluvial" period, and the Northern regions in the Elephantoidal era. Climate of the North-  
ever for a long time previous, there existed in Europe elephants, rhinoceros, hippopotamus, lions, and hyænas, besides bears, the glutton, wolves, foxes, the horse, oxen, the urus, deer, beavers, hares, rabbits, water-rats, &c., we are presented with a problem of considerable interest relating to the state of the climate at that period. The most abundant, perhaps, and most generally diffused of all these remains are those of the elephant and rhinoceros; though in particular cases, bears or hyænas fill whole caves, and the horse, ox, and urus are very plentiful in gravel and marl. So many animal remains of genera now exclusively confined to hot climates, have induced many Geologists to conclude that the Northern regions of the Globe were at that time much hotter, and that their total extinction was occasioned by a sudden refrigeration of the climate. On the other hand, the glutton, the urus, wolves, foxes, bears, horses, and large horned deer, and beavers, appear as characteristic of cold or temperate climates, and furnish arguments for the doctrine that the animals resembling those now living in tropical regions, were fitted by some peculiarity of constitution to support the rigours of the Northern zone. These statements are so equally balanced, and the authors who support them so respectable, that no impartial inquirer can pronounce between them without further evidence. This evidence must be of a particular kind. It will be of little use to add to the number of animals on either list; and as the species are different from those now in existence, the relative power of adaptation to climate of their several living analogues will not be sufficient to settle the point. We must find the remains of some of these animals, in such condition, or accompanied by such collateral circumstances, as to characterise the climate independently of the generic relations of the animals.

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on this sub-  
ject.

Two cases coming within these conditions are known to Geologists, of so distinct a kind, and leading so positively to the same conclusion, as to leave little room for further discussion. The first is the instance of an elephant, of the same species precisely as that usual in diluvial accumulations, being found in 1804, enclosed in solid ice, at the mouth of the Lena, where that Siberian river flows into the Arctic Sea. It was a perfect animal, with tusks in the jaws, and had evidently been entombed in its icy sepulchre immediately after death, for the flesh of its huge body was not decayed, but actually furnished a feast to the wolves and bears of the coast; the skin remained entire, and its whole surface was covered with *hair of two kinds*, one shorter and finer near the body, the other coarse and bristly, and even sixteen inches long. It is to be regretted that the difficult circumstances of the country did not permit Mr. Adams to examine minutely the anatomy of this specimen, thus wonderfully preserved through the fluctuations of ages; but the skeleton, mounted at St. Petersburg, furnishes sufficient characters to prove its perfect agreement with the fossil, and its distinctness from either of the living elephants. Here then is a plain proof that the fossil elephant was fitted, by an appropriate clothing, to withstand the occasional cold of a high Northern latitude, not perhaps to exist on the shores of the icy sea, but to inhabit about the sources of the Siberian rivers, and over the whole extent of Europe and a part of North America. The North coast of America, as well as that of Siberia, encloses abundance of the remains of these elephants in cliffs of frozen mud. (Capt. Beechey.)

The conclusion from this fact is rendered still more decisive by the discovery, in 1770, of the fossil rhinoceros tichorhinus, under the same extraordinary circumstances of preservation of flesh, on the banks of the Wiluji, which falls into the Lena below Jakoufgk, and its body was likewise covered with hair.

Dr. Buckland's conclusion of some remarkable catastrophe and sudden refrigeration of the Siberian regions and the borders of North America, near Behring's Straits, seems to offer a reasonable explanation of the extraordinary preservation of these remains, which besides may have been drifted from their original seats Northwards.

The second case is the discovery together in the same marl pit, connected with gravel deposits, near Market Weighton, in Yorkshire, of the remains of elephant, rhinoceros, lion, wolf, horse, urus, ox, deer, &c., species all or nearly all extinct, with thirteen species of land, marsh, and freshwater shells now living in the neighbourhood. Now as hardly any animals are more remarkably limited in climate, and restrained by local circumstances, than the molluscous tribes of the land and fresh waters, as the number of the species here discovered is considerable, and their identity altogether certain, without a single extraneous species, it is a safe conclusion, that the climate in which they lived was that which England and the central parts of Europe now enjoy; for such mollusca become mixed with other races on approaching the Mediterranean, and many of them cease to exist in the colder latitudes of Northern Europe. The same conclusions result from the examinations of that remarkable deposit called "Loess," in the valley of the Rhine, where the extinct elephants and rhinoceros lie with many existing land shells. (Horner.) Hence we conclude, with confidence, that the antediluvian climate of the Northern parts of the Globe was

nearly the same that it is at present; and it is no great objection to this view, that the banks of the Frozen Sea will not now feed an elephant, because, in the first place, it is not yet proved that the elephants were not drifted by the long Siberian rivers to their frozen mouths; and secondly, our conclusion is for a temperate or cold, not frigid climate, as distinguished from the torrid climate, to which some Geologists would unmercifully subject these animals in their warm Winter dress.

Nearly all the propositions that we have endeavoured to establish concerning the important subject of diluvial accumulations will be admitted by theorists of every order. That the Earth has been covered over a large extent, since the completion of nearly its whole apparent series of successive marine formations, by tumultuous floods of water, powerful enough to dislodge and transport, hundreds of miles from their native sites, huge blocks and fragments of rocks, and to destroy the races of animals then living in those Countries, and to produce considerable changes in Physical Geography, is a fundamental doctrine of modern Geology. But questions of considerable difficulty, which might perhaps have been postponed to a later period of the investigation, if the Science had been permitted to follow its own secure course of observation and induction, are forced upon our attention by the anticipations of theory, and the premature anxiety felt, even by writers on Geology, to establish parallels of time between the Geological datum of the destruction of certain land-animals and the Noachian Deluge.

We have shown that these diluvial floods were very extensive, but we are required to answer further whether they were *universal*. We have proved them to have belonged to a certain limited zoological era; but we are asked, were they *simultaneous* over the globe? We have admitted that they have effected changes in the physical features of the Earth's surface, but we are called upon to state whether *valleys* were excavated by their agency.

This is the place to discuss the two former questions; the latter, though often mixed up with the others, will admit of clearer solution by first examining the action of existing causes in modifying the surface of the Earth.

The doctrine of the *universality* of the diluvial currents, was adopted by Geologists, according to their interpretation of the connection between Geology and the Hebrew Scriptures, long before they had acquired the power of clearly tracing the effects of such currents across their own hills and valleys; and after Mr. Smith had fixed some of the leading characters of the diluvial detritus in England, they were hastily, by anticipation, applied even to Countries never visited by any observer. Subsequent researches have to a certain extent justified this boldness; and the discoveries of Buckland and Cuvier, by fixing zoological characters for the diluvial periods, have harmonized the results into a system. But it is unsafe at present to venture such a doctrine as the universality of the diluvial currents, even upon the admission that their powerful traces are recognised over nearly the whole Northern hemisphere. If, indeed, it should eventually be proved, that diluvial currents have constantly followed upon the elevation of large tracts of land above the sea, their universality might be safely inferred, since nothing can be more clear than the former submersion of all our continents. But this would not satisfy all the conditions of the problem; as in diluvial gravel and caverns so closed there would be no reason to expect the bones of land-animals, and it is a matter of notoriety that the elevation

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the phenomena

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of land above the sea, instead of being confined to the mastozoötic era, has proceeded at intervals through the whole Geological period.

It must, indeed, be owned that many mountain ranges were uplifted at the periods alluded to, but we dare not so far deviate from the method of observation and induction which has raised Geology to its elevated rank among the Sciences, as to assume universal inundations of the Globe, to follow confessedly partial disturbances of the bed of the Ocean. On this, as on many other questions, we must appeal to further observation.

Length of  
the diluvial  
period.

The doctrine of *simultaneity* of diluvial currents over the Globe, was introduced by the same desire to accommodate Geological theory to the ordinary interpretation of the Mosaic record, and involves considerations of great difficulty. To determine whether diluvial phenomena are traceable over a greater or less extent of the surface of the Earth is the work of observation. To settle the date of these phenomena with reference to one another is a very nice and difficult subject of analysis and inference. Even if it were the fact that the diluvial detritus in different Countries was scattered by the devious currents of one simultaneous inundation, it is doubtful whether satisfactory Geological evidence could be collected to *prove* this. No single deluge of such vast extent has been disclosed by investigations of the phenomena of earlier date: we see no agencies, either cosmical or terrestrial, likely to occasion it now; it cannot, therefore, be *assumed*, as a natural phenomenon, without violation of the rules of Philosophy.

But though, strictly speaking, the question of the *simultaneity* of the diluvial catastrophes in different regions is inadmissible in the present state of our knowledge, we may modify the inquiry so as to bring it within the scope of examination. Let us inquire if the diluvial phenomena of all Countries in which they have been observed, have so much of a common character as to point to the same *kind* of cause, so much of a common direction as to be assignable to causes having the *same local origin*, and are accompanied by such collateral circumstances as to be limited within an *assignable period of time*. The first point is already answered in the affirmative by all the preceding observations; on the second point, we may observe that a considerable number of observations indicate a prevalent direction of currents from the North, but many others appear to refer the local origin of the currents to the neighbouring mountains. The third part of the inquiry has also been met in part by the history of the animal remains in the diluvial and antediluvial deposits; for these clearly belong to a limited zoological period, and as this period appears to have been terminated in each district by the diluvial catastrophes, we are justified in believing that the time during which the turbulent waters flowed was comparatively short. To the same conclusion we must necessarily arrive, from a comparison of the diluvial disturbances with those of older Geological periods.

But short as this period was, we are able to divide its characteristic phenomena into successive stages. There are few parts of England, where the diluvial masses do not consist of more than one kind of deposit, derived from a current in one direction. On the coast of Yorkshire the general base of the whole diluvium is a thick mass of clay, with heaps of fragments of rocks derived from Cumbria and North-Western Yorkshire scattered through it. In some places this rests upon water-moved chalk and flints; in others it is surmounted by

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beds of gravel and sand, which are themselves, near Bridlington, covered by thick layers of chalk and flints from the neighbouring wolds. But we must be careful not to infer from this and similar facts more than they will bear. The lapse of time is here proved, but as no deposit intervenes implying that the time was considerable, as the lower diluvium is not water-furrowed to admit the upper, as the same characteristic animal remains are found in several portions of the deposit, it is possible that all these successive diluvial masses might be brought by the varying impetus of one continuous or intermittent general convulsion. De Beaumont, from his admirable survey of the Alps, infers with great probability that the diluvium around these mountains belongs to two distinct periods, and was occasioned by two separate convulsions affecting the Alps. By the former convulsion, which elevated the Western Alps from Dauphiné to Mont Blanc, prodigious quantities of debris rolled off to the West, and by the second convulsion, which elevated the Eastern Alps from Mont Blanc to Vienna, the old diluvium was dislocated, and floods were occasioned, which transported a great quantity of materials over the detritus of the former period. Here, also, we must be cautious in the inference. That *some intervals* happened amidst the diluvial disturbances, that the diluvium is of *unequal antiquity* is clearly proved; but nothing has yet been established contrary to the general view of this subject, which we have before suggested, viz. that the diluvial phenomena were produced during a *comparatively short period* of convulsion of the land, and consequent agitation of the sea, ensuing upon the completion of all, or nearly all the marine strata, now apparent above the sea, and subsequent to the habitation of at least the flatter regions of the Earth by various races of quadrupeds now extinct. This is all that can be safely asserted in the present state of Geology.

In all the periods of time which elapsed during the formation of the stratified rocks, there is no evidence that Man was a dweller on this Globe. Not in the most recent of the tertiary strata, neither in the littoral nor in the lacustrine deposits of that period, have any traces of Man or his works been perceived. This ought in no degree to surprise us, for all the animals and plants of that and earlier periods were *parts of an earlier system* of organized nature. But it appears something extraordinary that bones of men and vestiges of human art should have been so rarely found in any of the ascertained deposits of the diluvial era, except under dubious or explanatory circumstances, since at that time the earth had assumed its present form and appearance, and was inhabited by races of quadrupeds which, if not specifically the same, were, for the most part, closely analogous to those which now live; in particular, the horse and domestic cattle, animals so singularly serviceable to and dependent on Man, existed in great plenty in the Northern zones, and, therefore, the *present system* of organized nature, of which Man is the head, may be said to have commenced.

That the bones of men are as durable as those of quadrupeds, is established by comparisons made on fields of battle, and, therefore, if he lived with the mastozoötic quadrupeds, his remains should, under some circumstances or other, be found mixed with theirs. Dragged into a den by the prowling hyæna, or accidentally lost in a fissure, or overwhelmed by waves and buried in diluvium, we should frequently meet with the bones of our ancestors. Old writers, who saw in every

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thing only the traces of a general deluge, are full of discoveries of the bones of men; but modern anatomy has assigned them to their true analogies, the elephant, salamander, and saurian. In modern times a few examples of bones of men, found under circumstances arguing great antiquity, have been recorded. Upon strict examination it appears that in most cases these remains belong to a later epoch than the diluvial convulsions: the petrified bodies of the coast of Guadalupe are enveloped in comparatively recent accretions; the human remains of the valley of the Elster, near Leipzig, appear to have been inhumed since the general dispersion of diluvium; the woman found in Paviland cave was of an early British era. The only cases remaining for further examination are some caves in the South of France, where the remains of Man and rude pottery are found mixed with a quantity of bones belonging to extinct species of animals of the mastozoötic era; superficial deposits in Baden and in Austria, where remains of men with depressed skulls (as if occasioned by unnatural bandages) are found; and the remarkable notices by M. Boué of mingled human and animal remains in the breccia of Nice and Dalmatia.

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of France.

Without stopping to discuss the yet imperfect evidence concerning the antiquity of these remains in the breccia and superficial accumulations, we shall pass to the consideration of the caves in the South of France. From the examinations of Tournal, Christol, and Mangel de Serres, a considerable body of evidence has been collected concerning the caverns of Bize, (Aude,) Durtfort, Pondres, Souvignargues, (Gard,) and from the similar state of conservation as well as mixture of the bones of men and animals in the caverns of Bize, M. Tournal decides positively that their age is the same. These animals are stag, chamois, roebuck, antelope, and bear, which hardly require to be considered of the mastozoötic era. The same conclusion was drawn by M. Christol, from subsequent researches in the caverns of Gard, in which the animal remains were decidedly of the same era as the fossil elephant and rhinoceros. But the most instructive, probably, of all these discoveries, is that of the cavern of Miallet, near Anduze, (Gard,) completely investigated by M. Teissier. This grotto, situated on the banks of the Gardon, is opened in a dolomitic rock subordinate to the lias, on a steep slope, thirty metres above the valley. The lower layer of the interior of the grotto is dolomitic sand, irregularly overspread by a thin stalagmitic crust, and in places by an argillo-ferruginous mud, more than a metre thick, and adhering in several places to the roof and sides. In this bed were discovered in great abundance, and excellent preservation, bones and teeth of large bears, and with them a few bones of hyæna, ruminantia, and birds; under the stalagmite, and under a bed of loamy sand from two to four decimetres, a great number of human remains was found in various parts of the grotto. In the depth of the cavern they are unquestionably mixed with the bones of bears, which predominate; towards the entrance, on the contrary, human remains are most abundant, and appear of less antiquity. Upon the ossiferous loam, under a little projection of rock, was discovered a human skeleton nearly entire, near it a lamp and small figure in earthenware; further off bracelets of copper; in other situations coarse pottery, wrought bones, and edge tools of flint, indicative of ruder industry. The human skulls were depressed from above, apparently by artificial means, thus presenting a

deceptive resemblance to the negro, though really belonging to the Caucasian race of men.

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M. Teissier infers from these data that the accumulation of distinct periods can be traced in this cave:—1. The mastozoötic or antediluvian era of the bears, with whose remains those of men are mixed, perhaps by subsequent natural or artificial means. 2. The era of rude civilization, (probably Celtic,) when the coarse pottery, flint tools, &c. were introduced, perhaps, to grace the sepulture of individuals. 3. The era of Roman Arts.

There is no necessity of hazarding a definitive conclusion on the antiquity for these human remains, because there is very great probability of gathering much additional information by the discovery of new caves under different circumstances. In the mean time we may remark that the principal arguments for the coeval existence of men, and extinct pachydermata and carnivora in the South of France, is the intimate mixture and equal conservation of the bones; and these arguments should not be slighted, for they would, probably, not have been resisted in any case of the mixture of quadrupedal remains. On the other hand, the known facts that many parts of the Mediterranean shores were anciently possessed by Troglodytic nations, and that the custom of burying in caves, as well as retiring to them for safety, was very general in these Countries, adds great force to the opinion of M. Desnoyers, that, in most cases, the human remains are of no greater antiquity than the early Celtic Ages, in which very similar works of Art were executed. (See Desnoyers, *Rapport à la Soc. Géol. de la France*, 1831.)

It is clear that ossiferous caves have received their contents, some at one period, and some at another, and that in others operations of the same kind, repeated at very different periods, have consigned to our investigation monuments of all the great zoological changes which have happened on the dry land since it first became tenanted by mammalia. The whole subject must yet receive a great accession of well-observed facts. One remark, concerning the excessive rarity or non-existence of human remains in diluvium, and in caves of the elephantoid era, may be of considerable importance. Those parts of the Earth's surface to which traditions and, perhaps, general reasoning, seem to point as the first sites of the human race, the central regions of Asia, have been as yet little examined with reference to this question. It may be very possible yet to discover them there even in abundance, though in the high Northern regions men may not have existed till much later periods. It is a singular fact that the *Quadrupana* or monkey tribes which, so nearly approach to the bodily organization of man, are equally absent from the deposits of which we are speaking.

Upon the whole, the evidence yet obtained concerning the *Geological period* when the human race began to exist on the Globe, is very imperfect, and we may, perhaps, wait long for more full information. In the mean time, it may be stated as a general admission that Man did not exist on the Globe during the secondary, and, probably, not during the epoch of tertiary formations, and that sufficient evidence for his coexistence in Northern climes with the mammoths and hippopotami is yet wanting; but as the races of oxen, horses, camels, &c. had then begun to exist, it is a reasonable expectation that, eventually, this question will be decided in the affirmative.

We shall conclude our remarks on this interesting

class of deposits by some attempt to assign the causes of the diluvial phenomena. Those who refer these effects to one universal flood sweeping over the whole Globe, must of necessity ascribe such a mighty catastrophe to some great astronomical cause, such as the appulse of a comet, or the displacement of the axis of the Earth, or appeal to a miracle. But as we cannot venture to assume that what we name diluvial phenomena are of universal extent, or were occasioned by a single convulsion, nor are entitled at our pleasure to disturb the harmony of the Solar system, nor to help our ignorance by invocation of miracles, these conjectural hypotheses must be passed by in silence. From what has been previously stated, we are entitled to look upon the diluvial epoch as a short period of violent tumult in the ocean, like many which have happened before; perhaps more extensive, but certainly similar. Why, then, should we not refer it to the same causes? As the elevation of the beds of the sea after the grauwaacke period, after the carboniferous period, after the cretaceous period, produced large and violent floods, and caused the formation of extensive conglomerates, so the elevation of the Alps may have caused the diluvium which has

rolled from them, and the elevation of the Scandinavian chains may have caused the transport of their granites, sienites, and limestones across the Baltic, and along the plains of Germany. That the Alps have been elevated from deep sea is the universal conclusion of observers; that the whole chain has been raised at a comparatively recent period is certain; and there appears every reason to believe that the dispersion of the boulders was consequent upon the elevation of those parts of the Alps from which respectively they were detached.

We cannot apply this mode of reasoning to the Cumbrian mountains in England, for these appear to have been elevated above the sea at a far earlier epoch than that now under discussion. In this case, then, the effect must be ascribed to a cause acting from a distance, which would agree with the magnitude of the phenomena observed, and lead to the notion of some very general convulsion preceding the diluvial movements. Upon the whole, we will venture to conclude that the diluvial currents were occasioned by convulsive movements of parts of the solid fabric of the earth, of sufficient force to throw the waters of the sea over distant regions of dry and elevated land.

*Table of Organic Remains in Caverns and Superficial Deposits subsequent to the Tertiary Period.*

N. B. Extinct genera are marked with an asterisk. Caverns marked with (c.) Breccia with (b.)

Name.	In Caverns and Breccia of all Ages.	In Diluvial and Earlier Accumulations.
Remains of men.....	c. Gailenreuth, Zahnloch, Paviland, Bize, Durtout, Pondres, Souvignargues, Sicily ....	Kostritz, Rhine Valley, Austria, &c.
Vespertilio .....	b. Nice, Daumana c. Franconia, France .....	Kostritz.
Sorex .....	b. Cagliari, Antibes. c. Avison.	
Talpa .....	b. Sardinia, Dalmatia .....	Ditto.
Ursus spelæus, Blum. ....	c. Avison .....	Ditto.
arctoides, Blum .....	c. Germany, France, England .....	Chatillon.
eultridens, Cuv. ....	b. Kraai, near Krems, Münster .....	
other species .....	c. Franconia, Bize, Sallèles, Lunel Vieil.	Val' d'Arno, Puy de Dôme.
Nasua, Cuv. ....	c. Sandwich, Kent's Hole .....	
Meles vulgaris .....	c. Franconia, Sandwich, Fouzan, Sallèles.	Puy de Dôme
Gulo spelæus .....	b. Perpignan .....	
Viverra, Cliff. ....	b. Nice.	
Canis spelæus, (Wolf.) ....	b. Lunel Vieil, Sallèles.	
familiaris .....	c. Gailenreuth, Sandwich	
other species .....	c. and b. Australia	
Vulpes vulgaris .....	c. Franconia, Bize, Sallèles, Kirkdale. ....	Yorkshire.
Hyæna spelæa, Goldf. ....	b. Sardinia.	
other species, Goldf. ....	c. Lunel Vieil.	
Felis spelæa, Goldf. ....	c. Franconia, Bize, Sallèles .....	Val' d'Arno, Avaray.
antiqua, Cuv. ....	b. Sardinia; c. Kirkdale .....	Perrierburg.
other species .....	c. Kirkdale, Plymouth, Swansea, Paviland, Muggendorf, Harz, Fouvent, Sandwich, Lunel Vieil, Pondres, Kent's Hole, &c. ....	Kostritz, Canstadt, Eichstadt, Val' d'Arno, Hertzburg, Abbeville, Lawford.
Mustela (polecat) .....	c. Franconia, Sandwich, Lunel Vieil .....	Puy de Dôme, Velay.
(wiesel) .....	c. Kirkdale, Plymouth, Gailenreuth, Baumann's Höhle, Sandwich, Lunel Vieil .....	Kostritz, Val' d'Arno, Bielbecks in Yorkshire.
Lutra antiqua, M. de S. ....	c. Gailenreuth; b. Nice.	
other species ? .....	c. Lunel Vieil, Gailenreuth.	Upper Italy, Puy de Dôme.
Dasyurus, Hypsiprymnus .....	c. Kirkdale.	
Phascodomys, kangaroo and wombat .....	c. Lunel Vieil.	Puy de Dôme.
Castor .....	c. Australia. (Cliff.)	
*Trogontherium Cuvierii, (Fisch.) .....	c. Lunel Vieil. ....	Val' d'Arno, Puy de Dôme.
Wernerii, Cuv. ....		Taganrok, near the Sea of Azof.
*Osteopora platycephala (Harlan) .....		Jaroslav.
Mus .....	c. Kirkdale, Sallèles .....	Near the Delaware.
Arvicola .....	b. Gibraltar, Sardinia .....	Lawford
Hystrix .....	c. Kirkdale, Gailenreuth, Sandwich, Gibraltar, Nice, Cetta, Corsica, Sardinia.	



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Name.	In Caverns and Breccia of all Ages.	In Diluvial and Earlier Accumulation
<i>Lepus diluvianus</i> and others. . . . .	a. Kirkdale, Franconia, Sundwich . . . . . b. Cetta, Corsica, Nice . . . . . d. Sardinia, Gibraltar, Cetta, Nice.	Puy de Dôme.
<i>Lagomys corsicanus</i> , Brurdet . . . . .		Ditto.
<i>Chloxomys</i> . . . . .		North and South America.
* <i>Megatherium Cuvierii</i> . . . . .		Ditto.
* <i>Megalonix Jeffersoni</i> . . . . .		Puy de Dôme.
<i>Dasypus</i> , Bravard . . . . .		
<i>Elephas primigenius</i> , Blum. . . . .	c. Kirkdale, Warksworth, Mendip, Swansea, Muggendorf, Fouvent . . . . .	Very generally in Europe, Asia, and North America.
<i>meridionalis</i> , Nesti . . . . .		Upper Italy, Puy de Dôme.
<i>priscus</i> , Gold., resembling the African elephant . . . . .		Yorkshire, Rhine Valley, Wittenberg, Russia.
several other species, according to Fischer . . . . .		Russia, Podolia.
* <i>Mastodon maximus</i> , Cuv. . . . .		Very general in North America, Norfolk. (Smith.)
<i>angustidens</i> , Cuv. . . . .		
<i>andium</i> , Cuv. . . . .		Andes. (Humboldt.)
<i>Humboldtii</i> , Cuv. . . . .		Chili.
<i>elephantoides</i> , Clift. . . . .		Irawadi in the Birman Empire.
<i>latidens</i> , Clift. . . . .		Ditto.
<i>arvernensis</i> , C. and J. . . . .		Puy de Dôme.
<i>Hippopotamus major</i> , Cuv. . . . .		In England very generally, Upper Italy, Puy de Dôme.
undetermined . . . . .		Irawadi.
<i>Rhinoceros tichorhinus</i> Cuv. . . . .	c. Palermo, Australia . . . . . c. Kirkdale, Warksworth, Plymouth, Swansea, Harz, Sundwich, Fouvent . . . . . b. Nice.	Siberia, England, Germany, France, Val' d'Arno
<i>leptorhinus</i> . . . . .	c. Lunel Vieil . . . . .	Cussac.
<i>minutus</i> Cuv. . . . .	c. Lunel Vieil, Pondres, Souvignargues.	
<i>elatus</i> , C. and J. . . . .		Puy de Dôme.
undetermined . . . . .		St. Privat d'Allier.
* <i>Elasmotherium Fischeri</i> . . . . .		Siberia.
<i>Equus</i> , perhaps more than one species . . . . .	c. Bize, Salles, Argon, Pondres, Lunel Vieil, Fouce, Kirkdale, Mendip, Clifton, Plymouth, Swansea . . . . . b. Nice, Antibes, Gibraltar, Dalmatia, Arragon . . . . .	Kostritz, Brunswick, Canstadt, Val' d'Arno, Oxford, Essex, Yorkshire, (frequent,) Lawford, &c.
<i>Sus</i> . . . . .	c. Mendip, Bize, Franconia . . . . .	Oxford, Val' d'Arno.
other species . . . . .	c. Sundwich . . . . .	Puy de Dôme.
* <i>Choropotamus</i> . . . . .	b. Villefranche-Lauraguais . . . . .	Irawadi.
* <i>Meriotherium Sibericum</i> . . . . .		Siberia.
<i>Cervus megaceros</i> , Hart. . . . .	Kent's Hole . . . . .	Very general in lacustrine deposits, probably less ancient than the diluvial deposits, England, France, Ireland
<i>tarandus priscus</i> . . . . .	Breugue . . . . .	Europe.
<i>tarandus</i> . . . . .		Kostritz.
<i>dama giganteus</i> . . . . .		Abbeville.
<i>polignacus</i> . . . . .		Cussac.
<i>elaphus</i> . . . . .	In English caverns generally . . . . .	Frequent in England.
<i>Reboullii</i> , Christol. . . . .	c. Bize, Salles . . . . .	
several others . . . . .	c. Ditto, ditto . . . . . b. Gibraltar, Cetta, Nice, Antibes, Pisa . . . . .	Cussac, Puy de Dôme
<i>Antelope Christolii</i> , M. de S. . . . .	c. Bize, Salles . . . . .	
other species . . . . .	b. Nice, Arragon . . . . .	Irawadi, Kostritz.
<i>Ovis</i> . . . . .	b. Villefranche-Lauraguais . . . . .	
<i>Bos primigenius</i> , Bojanus . . . . .	c. Salles, Bize, Lunel Vieil, Argon, Pondres, Souvignargues . . . . .	
<i>priscus</i> , Boj. . . . .	c. Bize, Souvignargues, Lunel Vieil, Pondres, Argon, Salles . . . . .	Siberia, North America, Yorkshire, and various parts of Europe.
<i>bombifrons</i> , Hart. . . . .		Bigbourne Lock, &c.
<i>trochoceros</i> , Von Meyer . . . . .		Upper Italy.
<i>Pallasii</i> , DeKay . . . . .		Siberia, New Madrid
<i>Velaunus</i> . . . . .		Cussac.
undetermined . . . . .	Kirkdale, Mendip, Plymouth, &c. . . . .	In various parts of England.

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We have not ventured to admit into the preceding list, the numerous remains found in the iron sands of Eppelsheim, which are stated to be related to the tertiary limestones of that vicinity, in which also (see Meyer's *Palæologica*) bones of rhinoceros, &c. occur. These remains consist of species of gulo, felis, (not those of the caverns,) several small rodentia, cricetus vulgaris? moschus antiquus, 5 species of cervus, (not those of the diluvium,) rhinoceros Schleiermacheri, (Kaup,) mastodon angustidens, m. arvernensis, 3 species of equus, tapirus priscus, lophiodon Goldfussii, sus antiquus, s. palæocherus, dinotherium giganteum, d. bavaricum, manis gigantea

It may be remarked that in the valley of Rhine, and in some other parts of the Continent of Europe, where local tertiary seas have left agitated deposits along their shores, and in the line of their currents, it requires extreme caution to apply with propriety the term diluvial. By an appeal to the organic exuvie, where these are sufficiently plentiful, it may often be possible to resolve the doubt, especially where remains of the pachydermata are numerous. Thus elephants, hippopotami, rhinoceros tichorhinus, and certain bovine and cervine remains on the one hand, and, on the other palæotheria, lophiodonta, &c. offer strong contrasts. But this test cannot always be applied, and it then becomes difficult to rely on

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the minute distinctions which probably almost always exist between the tertiary and diluvial species of the same genus. In this research much yet remains to be effected. Cases like those of Eppelsheim and Georgsgund become in this point of view exceedingly important; for, by a comparison of many such instances, the series of zoological changes on the land, between the beginning of the tertiary and the end of the diluvial periods, may perhaps be eventually determined. At present we can only perceive that in general the palæotherian inhabitants of Europe had mostly ceased to exist in these limited districts before the elephantoidal races had spread themselves so widely over the Northern zones; and can clearly show that the proportion of species belonging to extinct genera in the undoubted tertiary deposits, was at least half, while in the undoubted diluvial deposits and caverns of the same date, it was about one-fifth. The remarkable extinct genus mastodon is common to the tertiary and diluvial periods, and there seems good reason to think that in some of the localities in North America, remains of these animals lie in postdiluvial lakes, like those which contain in Ireland and Yorkshire the bones of the cervus megaceros. Some remarks bearing on the general question of the determination of the Geological epochs of marine and littoral deposits, by comparison of their quadrupedal remains, will be found under the head of the tertiary strata.

#### *Deposits of the Modern Era—Modern Causes in Action.*

Relation of  
terrestrial  
agents in  
ancient and  
modern  
crust.

Having now concluded our descriptions of the strata and aqueous products recognised in the crust of the Globe, and also traced the effects of subsequent extraordinary inundations upon the surface, arising from local changes of level or general internal convulsions, it remains to be seen whether the causes now in action in the modern economy of Nature are of the same kind as those which were formerly concerned in producing the arrangements and disarrangements observed in the crust of the Globe.

This is the true cardinal point of theory. According as the one or the other conclusion on this point be adopted, we may attempt to explain the ancient phenomena by modern laws of Nature, and thus connect the present and the past, the extinct and the existing history of our Planet into one system of progressive change, according to the school of Hutton, Playfair, and Lyell; or suppose that in the chaotic infancy of our Planet, laws peculiar to that period prevailed, and properties of matter were unfolded then which never show themselves at present; and that the ancient rocks and organic bodies belong to a wholly distinct set of causes, were the produce of a peculiar creative impulse, no longer permitted to operate on the finished and man-inhabited Planet. The Wernerian cosmogony bears very much this aspect.

But though, put thus in direct opposition, the rival hypotheses appear to have no point of union, we find, in fact, that between the opinion of Hutton, who considers Creative Nature to be perpetually in progress,—the same to-day, yesterday, and for ever—and the dogma of Werner, that the World was made by a certain settled sequence of events, to which nothing similar now happens, every variety of theory is adopted and defended. We may, however, with rigid accuracy and much convenience, rank them in three classes.

1. The favourers of Hutton's and Lyell's views, who maintain that the causes now in action to change the

level and alter the relations of the masses of matter near the crust of our Globe, are those which have ever been in action, identical in kind, and equal in degree, in all times past, and which may be expected to continue the same, in kind and degree, through the future.

2. The general School of English Geologists, who have always maintained, and laboured to prove, that the causes operating on the surface and in the interior of the Earth have remained through all times past unchanged in kind, and are still operating with the same tendencies as they always did, but on smaller areas, and with less effect. This view of the subject has a double aspect. English Geologists have generally believed that as volcanoes were supposed to become languid through want of fuel, the circumstances under which the modern operations of water and fire are manifested in the general economy of Nature, approach more nearly to a state of equilibrium or saturation, and therefore afford no opportunity for the same extraordinary display of energy as in ancient times; but since the relative periods of the great convulsions which have elevated chains of mountains, and given new boundaries to the ocean have been investigated upon sound principles, the mind has become gradually familiarized to another notion, and habituated to contemplate long periods of ordinary and regular action of natural causes, interrupted by transient local or general convulsions. According to this modification of the hypothesis, the present is a period of ordinary and regular action, succeeding upon an epoch of violent disturbance.

3. The old notion of despairing speculators in cosmogony, who found it easier to cut the Gordian knot, by flatly denying the analogy of modern and ancient operations, and either referring the whole beautiful order of the ancient works of Nature which they could not comprehend, to a momentary fiat of Deity, or to the rude and prolonged confusion of elements in chaos.

This is the only notice we shall take of that mere dream of indolence and deficient observation; for we have already proved that the stratified rocks are certainly analogous in all points to the products of modern waters, and that the unstratified rocks clearly prove their special origin from fire.

As in our accounts of the construction of the Earth's crust we have resolved to separate the results of the ancient operations of fire and water, so in our views of the modern effects of these agents, the same plan will be followed; and, without stopping at every point to settle the precise amount of inference due to every datum, we shall present a connected view of the continual effects of the atmosphere, rains, springs, rivers, and the sea, on the surface of the Globe, before proceeding to the changes occasioned by more occasional eruptions of igneous agents from below, volcanoes and earthquakes, and other connected phenomena. Some general inferences, suited to the present state of the Science, may occasionally be ventured, and perhaps many years must pass before any one acquainted with the peculiar temptations to insecure hypothesis which sciences of observation hold out, will venture to dignify his imperfect generalizations with the delusive title of a Theory of the Earth.

#### *Wasting Effects of the Atmosphere.*

The gradual wasting of the surface of the higher parts of the Earth is an important element in Geological theory, and it is scarcely to be supposed that any Geologist can be

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Views of  
the English  
School on  
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so entirely engrossed with the contemplation of the ancient operations of water in producing the stratified crust of our Planet, as to neglect the consideration of the analogous effects which are in progress at the present time. The following examples of the varied effects of atmospheric influences, in modifying the surface of the erections of man and the works of Nature, are derived from the writer's own observations, and it is to be supposed that they form but a small part of the current information on the subject.

The wasting effects of the atmosphere are those initial or preparatory processes by which earthly materials are provided for rivers and the sea to transport and deposit in new situations.

These processes, as far as they depend on the atmosphere, are chemical when the atomic composition and the properties of the parts are changed, mechanical when their state of aggregation is altered; and this may happen by general humidity, variations of moisture, variations of temperature, or precipitations of rain.

It is not, however, always possible to distinguish accurately the effects of these several causes. Many natural agencies are often concerned in one operation, and the general result is the sum or the difference of their effects. The chemical effects of the atmosphere are evident in buildings and on the surface of certain rocks. The same process which slowly reconverts the mortar of walls into carbonate of lime, frequently causes the pulverization and bursting of the bricks, in consequence of the expansion of the small masses of lime which they contain.

The surface of bricks is often covered with a saline efflorescence, which is generally nitrate of lime, but sometimes muriate of soda. The surface of the yellow limestone near Doncaster is sometimes covered with a nitrous efflorescence, and so is the calcareo-magnesian mortar made from it.

The exterior of most uncrystalline rocks and buildings seems to be slowly eaten away by the moisture and carbonic acid of the air; but the influence of this destructive agent is most remarkable among the felspathic rocks, whether like granite they are originally crystalline, or like millstone grit composed of fragmented masses. The felspathic portion of the hypersthene rocks of Carrock Fell is so wasted that the crystals of hypersthene and magnetic iron are projected from the surface considerably. Some greenstone dykes are thus entirely decomposed to great depths from the surface, and whole rocks of granite, secretly rotten, wait only for an earthquake, or a water-spout, to be entirely reduced to fragments. Those who have seen the crumbled granite of Muncaster Fell, or Castle Abhol in Arran, surrounded by heaps of its disintegrated ingredients, must have been struck by the importance of this phenomenon in reasonings concerning the origin of many stratified rocks.

Both carbonic acid and oxygen act very decidedly upon the metallic, and particularly the ferruginous ingredients of rocks, and thus swell and burst them to pieces. Sometimes, however, this very cause seems to harden and bind together the rock, and to render it more durable, and in general, there is no certain test of the durability of any stone but experience under the same circumstances. The Bath stone, so permanent amongst its native hills, perishes in the salt air of Norfolk, and few calcareous freestones of any kind will long resist the carbonaceous atmosphere of London.

It is worthy of remark, that sculptured stones buried under ground are perfectly and even wonderfully pre-

served, while their fellows left exposed to the sky have been almost crumbled to dust. A fine example of this was noticed in the course of the excavations for the Yorkshire Museum, by which the statues which once stood between the arches of the nave of St. Mary's Abbey were discovered, some with blue others with red drapery, one with gilded hair, all retaining the most delicate chisel marks. A few yards from them, at the West end of the Church which they once adorned, the atmospheric influences have nearly obliterated a beautifully sculptured wreath of leaves round the doorway, so that Antiquaries have doubted whether they were meant to represent the vine or the ivy.

Frequently, in looking at buildings composed of porous materials, like the Portland stone, or a grit free-stone, we observe the parts which are overhung by a ledge, and thus kept in a state of continual shade and dampness, to be more rapidly consumed than the projections, but the parts which hasten soonest to decay are those near the ground. The same rules are exemplified in many remarkable rocks, as for instance in the quartzose conglomerates of the old red sandstone of Monmouthshire, and the millstone grit of Brimham Crags in Yorkshire. The "Buckstone" near Monmouth is a huge rock inversely conical, expanded above into a large area, but contracted below by continual waste to a narrow base of attachment. This process, a little further continued, might convert the buckstone, as probably some of the stones of Brimham have been converted, into a "rocking stone."

In Northern zones the variations of heat and moisture are greatest on the South and West fronts of buildings, and in consequence those fronts to our Cathedrals decay most rapidly. This is remarkably the case with the grand Cathedral of York built of magnesian limestone, which is in many places quite consumed on these fronts, but comparatively unimpaired on the Northern face.

The weathering of the surfaces of buildings by the fluctuations of heat and moisture is partly dependent on the structure and composition of the stone. The flagstone of Yorkshire is in many houses at Bradford gradually decayed grain by grain, so that the surfaces of the stone, continually renewed, and never permitting the growth of lichens, appear always neat and clean. The magnesian limestone of the same County, often traversed by veins of calcareous spar, presents frequently a cellular or honeycomb appearance, in consequence of the projection of these veins above the excavated limestone; but the coarse shelly beds of the Northamptonshire oolites, and the irregularly laminated millstone grit, are decomposed in lines corresponding to the inequalities in the composition of the stone.

In these cases the stone appears to undergo gradual and continual waste; but sometimes the whole surface exfoliates. Basalt very frequently suffers this kind of waste, granite not seldom, and it has been supposed in these instances, that the atmospheric action merely discloses the latent concretionary structure of the rocks.

The following examples require a different explanation. The bridge over the Wear beneath the Western towers of Durham Cathedral built (about 40 years ago?) of a sandstone associated with coal, is ornamented with a balustrade, and the little pillars are worked with various swellings and mouldings. In crossing this bridge many years since, the writer struck one of the balusters with his hammer, and being much

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Preserving  
power of  
the ground

Waste from  
humidity,

from  
changes of  
heat and  
moisture.

Waste of  
Felspathic  
rocks.

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surprised with the hollow noise which ensued, stopped to ascertain the cause. It was found, in many instances, that a thin, external coat of stone parallel to the mouldings was entirely separated from the internal nucleus, and ready to scale off upon the slightest blow. The Western front of the ancient and beautiful little Church of Skelton, near York, built of magnesian limestone, shows the same kind of decay in a direction across the bed of the stone. The Yorkshire flagstone is occasionally used, to make curb stones of two feet in height, the laminæ being placed vertically, and the block worked above to a semi-ellipsoidal figure. Even these laminated stones frequently exfoliate parallel to the tooled surface. The ramparts of Zurich are built of sandstone, belonging to the tertiary system, (molasse,) and the stones are cut with a boss along the middle and a depressed border. Desquamation happens parallel to the artificial surface.

Since, in these various instances, desquamations are found to occur parallel to the surface, without reference to the internal lamination of the stone, the mere circumstance of exfoliation seems insufficient to demonstrate the originally concretionary structure of basalt and granite. It is, nevertheless, very probable on other grounds, that basaltic pillars, if permitted to assume their natural shapes, without pressing one against another, would resemble a number of super-imposed spheroids.

All the cases of desquamation seem to arise from an alteration of the degree of coherence of the stone, whereby the external crust is made to expand and contract differently from the internal parts, and, in consequence, is soon separated from them. The surface of stones long exposed to the weather is frequently much indurated, while the inner parts remain soft. (This is the case in the outer circle of Stonehenge, Mr. W. Smith.)

from frost.

Frost is likewise an important agent in reducing to smaller masses the materials of the Earth. Some stone, if brought to the surface in Winter full of its "quarry water," will break in pieces directly. Advantage is taken of this circumstance by the slate-workers of Stonesfield and Collyweston, who quarry their stone in the Winter, taking care to shield it from the Sun and the wind till the frost has acted upon it, with the aid of affused water, if necessary, which, by disclosing the natural fissility of the stone, permit the blocks to be cleft into thin, sound, roofing slate. Landslips in mountainous regions are probably much accelerated by the power of frosts. In ascending the Righi from Weggis, on the Lake of Lucern, we are much struck by the extraordinary length and continuity of the joints of the *ungrünflue*. It is from these natural partings that the landslips fall, when repeated rains, snows, and frosts have worn or burst them open, and the water passing down them undermines the foundation of the cliff. Thus huge blocks, liberated from their attachments, roll down the steep descent, or half the summit of a mountain slides upon its argillaceous bed. Vast portions have thus slipped from the Righi towards the Isthmus which divides the Lakes of Zug and Lucern, and others are preparing to follow. The fissure is already opened parallel to the edge of the precipice, and previous below, so that a stone thrown in at the top, is said to fly bounding out at the base.

Effects of  
rain

We come now to the effects of rain, and without dwelling on the general degradation of the softer surfaces of the Earth caused by this agent, we shall proceed to show, that within the historic era hard and dur-

able stones have been greatly furrowed by the rain, and that in more ancient periods, the precipitations from above have carved themselves channels of various kinds, and sometimes occasioned real though miniature valleys of great length and continuity.

Many Druidical monuments in the North of England are constructed of coarse millstone grit, a rock admirably suited for yielding those enormous blocks preferred by the ancient Architects. Three huge Druidical stones, now standing near Boroughbridge, called the "*Devil's Arrows*," present us with a most instructive lesson on the ultimate fate of all human erections exposed to the ravages of time.

on monu-  
mental  
stones, &c.;

The rain, beating for 2000 years upon these venerable pillars, has cleft their tops, and ploughed deep furrows down their sides. The grooves are deepest at the top, and become wider and less distinct towards the bottom; they cross indifferently the false-bedded layers of pebbles, and go directly downwards. One of the stones leans remarkably and threatens to fall, but an examination of the furrows shows the inclination to be of most ancient date, for they descend much further down the pillar on the upper inclined face than on the under.

Similar effects of rains are visible to a greater extent on the bold crags, like Alnham cliff and Brimham rocks, which crown the summits of so many hills of North-Western Yorkshire, from some of which the Devil's Arrows were obtained.

In the valleys of Swisserland (Sarnen) blocks of limestone, which have fallen from the mountain sides, have been furrowed in the same way since their descent.

The carboniferous limestone of England has been little employed in building, except partially in old castles, where it seems durable, and they who know the magnificent ranges of scars which begird the hills of Derbyshire and Westmoreland, will acknowledge that few rocks seem more likely to endure the rage of the elements. But yet close inspection of these giant cliffs will prove that time has been busy there. The dry and bleached aspect, and the smoothed angles, show plainly the wasted surface. Those who have stood on Doward Hill, near Monmouth, to contemplate the rain-furrowed white limestone there, will not need another example. In the North of England analogous and more remarkable instances present themselves in the wide limestone base of Ingleborough, and in Hutton roof crags near Kirby Lonsdale.

The vast limestone floor which supports the cone of Ingleborough is marked in all directions by natural fissures, and divided into compartments like a map.

If one of these compartments be examined in the Western part of the mountain, its surface will be found scooped into little hollows which unite into a common channel, and terminate by indenting the edges and furrowing the sides of the fissure. They are, in truth, valleys in miniature, separately produced by the drainage, so to speak, of the several blocks.

The mere decomposing effect of the atmosphere produced on the edges of the stones a different effect, by wearing away the softer laminæ, but the smooth surface of the miniature valleys, their regular descent, winding course, and union into a common channel, show that they were fashioned by the repeated operation of descending rain.

This scar is nearly level, but in Hutton roof crags we

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have an opportunity of tracing the rain channels over an immense surface of bare limestone rocks lying nearly level on the hill top, but sloping rapidly down the sides to the East and South. On the level top of the hill the stones are variously worn in hollows and grooves irregularly united and running in different directions according to little variations of the ground; but on the steep East and South slopes the channels are extended into long furrows, which, uniting at acute angles, enlarge, widen, and descend the hill side, in lines following exactly the declination of the rocks, and stopped only by the few and distant fissures beyond which other systems of concurrent grooves begin.

Rain channels like miniature valleys.

It is impossible by drawings, or descriptions, to convey such an idea of the appearances of the Hutton roof crags, as to awaken in others the deep impressions which are fixed for ever in the mind of the observer. The astonishing resemblance which these little rain channels present to the great system of valleys which undulate the stratified rocks, seizes upon the imagination, and we re-examine all our notions of the origin of these great undulations. The fissures in the limestone rocks which stop and swallow up the gathered streams, are analogous to those longitudinal valleys beneath the escarpments of the oolites, and the chalk by which the rivers are turned at right angles to their earlier course, while the lower edge of the fissure corresponds to the escarpment itself, with its new system of denudations.

To see these rain and time-ploughed furrows winding in uncertain directions over the horizontal limestones on the hill top, like a slow river in a level plain, but running a straight downward course on the slopes, like a stream descending from its parent mountains, is enough to impress on every beholder a secure conviction that the excavation of valleys must be explained upon similar principles; that, as the feeble currents of descending rain, aided by long time, have been sufficient to plough their little courses, so the greater action of existing streams has been sufficient to work out their actual channels, though the excavation of the broad valleys in which they run, may have been accomplished by more violent and voluminous waters, flowing in directions predetermined by ancient subterranean movements.

Effects of inundations

It is probable that the slow but incessant action of rain, beating perpetually on the hard and the soft surface of the Earth, and removing grain by grain the materials loosened by the expansive agency of frost, moisture, and chemical changes, may be, in a given long series of years, more important in its effects than the violent water-spout, or the ravaging inundation of a bursting lake. Yet the effects of water-spouts are tremendous in Countries composed of easily destructible or unequally indurated materials. A water-spout which fell on the mass above Kettlewell in Yorkshire, committed the most terrible ravages in the narrow valley of the Wharfe, near Kettlewell and Starbottom. On the sides of the mountains in Cumberland, traces of these visitations seem utterly ineffaceable; and the memory of the sudden bursting of the Peat Bog above Keighley, will long be preserved in the valley of the Aire. The floods which rushed simultaneously from the Cairn Gorum and other mountains, in August 1829, over 5000 square miles of Aberdeenshire and other Counties, were of prodigious fury, removing hundreds of tons of large stones, whole acres of woodland, and almost hills of earth. The desolating effects of the bursting of the ice-dam

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which had formed the temporary Lake of Bagnes, are matters of history. The moving mass of water, mud, and monstrous rocks, which swept with violence down the valley of the Dranse, carried away forests, houses, bridges, cattle, and men. In six hours and a half it passed through an unequal and irregular course of forty-five miles, till its waves were lost in the Lake of Geneva.

Glaciers are likewise to be enumerated among the powerful agents by which the higher lands are wasted, and materials provided for the raising of the lower. As the Summer heat melts every year the lower portions of these long winding rivers of ice, and the heated ground thaws, and the gathering water dissolves their foundation, the whole mighty mass of snowy ice slides downwards on its sliding bed, ploughs up the stores, breaks up the rocks, and adding their spoils to the accumulations of the avalanches, throws to the sides huge banks of rubbish, provincially called *moraine*. The foot of the glacier is thus surrounded by an immense hill of loose materials which gradually find their way into the stream that issues beneath.

### Descending Streams and Rivers.

The wasting effects of the atmosphere, noticed in the preceding section, are sensible in all regions, and therefore in every Country some materials are provided for the streams to transport. But the proportion of matter thus prepared in mountainous Countries is so vastly greater than elsewhere, that in general the less conspicuous effects of the same causes in lower regions are overlooked. The common notion respecting the action of alpine streams appears to be, that *these* are the principal agents of destruction upon the faces of the mountains, and it is to them that the actual waste of the surface is attributed. But though these streams are indeed active agents of excavation, their principal influence is of quite another kind, and it is chiefly by the *disposition* of the materials brought into them by rains, avalanches, and water-spouts, that they effect such important changes.

In considering the action of streams and rivers, we must distinguish between their powers of eroding or excavating, and of transporting solid matter.

Erosion; excavating; action of streams.

The former is occupied on the channel and floodway, and its effects have relation to the *consolidation* of the matter traversed, and to the rapidity and volume of the moving water. About their sources, and for a long part of their early course, streams deepen continually their channels, and wear away their barriers of rock; but in their broad expansions near the sea, this power of excavation wholly ceases, as a general law, and is only evinced in particular cases, as when great bands are cut off or backs are undermined.

We have abundance of examples in all our mountain regions of the actual excavation of their channels by the rivulets and rivers. In the district of Aldstone Moor, the South Tyne runs to the North from the side of Crossfall, for some miles along a slope of shale, over the Tyne bottom limestone. In this shale, which is itself excavated into a broad valley, the river has evidently cut its own narrow yet sufficient channel; and no contrast can be more striking than that here afforded by the mighty valley of Tynedale, 1500 or 2000 feet below its bordering mountains, and the little channel holding the waters of the River Tyne. Every river in this manner works out its own channel in elevated regions,

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and in lower ground the soft clays and sands yield a passage to the feeble currents. In the level regions, along the rivers of Yorkshire and Lincolnshire, the channels have been many times changed, even by those sluggish streams, and still more in the deltas of the Rhine, the Nile, and the Mississippi; and among the Alps, this fluctuation of the river-courses is excessively irregular. No doubt, then, can remain of the fact that rivers and running waters excavate and alter their channels.

Mr. Lyell has given a remarkable case of the *recent* excavation in a bed of modern lava of a channel from 50 to several hundred feet wide, and 40 to 50 feet deep, by the River Simeto, flowing from Etna. Mr. Scrope has also shown similar phenomena to have happened in the volcanic region of Auvergne. In these cases the action of the river has probably been excited by the flowing of a current of lava across its course, so as to dam up the waters, and give them something of the force of a cataract.

Waterfalls,  
&c.

The waterfalls and cataracts upon the hue of a stream afford some curious points of study. It is especially in these cases that the increase of excavating power, derived by a river from the solid matter which it transports, is most sensible.

A cataract is formed upon the River Eden, in Westmoreland, near Kirkby Stephen, by some remarkable beds of calcareous red sandstone conglomerate, and the pebbles which the river brings down, here contribute with the whirlings of the water to excavate many deep perpendicular pits, similar on a small scale to swallow holes on the mountain limestone ranges, or those romantic cavities on the Caldew in Cumberland. Below many waterfalls in Wales and Scotland, the same effect is produced.

But the most characteristic effect of a cascade, is that ceaseless undermining of its base and sides, and consequent rupture of the spout or edge of the fall, which causes by slow degrees the cascade to retire further and further up the mountain side, and produces those awful and still deepening portals of impending rocks, which so much aggrandize the sublimity of a noble *waterforce*.

This effect may be excellently observed in the carboniferous limestone district of the North of England, where so many beautiful streams leap from the beds of limestone over perishing shales and sandstones, and rising in foam sap and undermine the base of a large semicircular cliff, till at length the solid limestone crown gives way, and the insatiable river renews its destroying attacks. The same thing is seen in many of the Swiss waterfalls, particularly in the manifold falls of the Giessbach.

Mr. Lyell very ingeniously applies the acknowledged fact of the recession of the Falls of Niagara, which appear to have been pushed back several miles, at the rate of 40 or 50 yards in 50 years, to the possible discharge hereafter, through the St. Lawrence, of the waters of Lake Erie. Such a discharge would, of course, occasion a local *déluge*; but the lake is so rapidly filled up by sediment, that it is a question whether it will not become dry ground, before the falls of Niagara shall have been pushed back so far as to be capable of emptying it. The fall of the Rhine at Schaffhausen is a grand exhibition of the erosive power of water, particularly the wearing of the base of the two island pinnacles of *gneiss* stone, which now stand proudly in the midst of the currents, but will eventually be hurled down the thundering cataracts.

In considering now the *transporting action of streams*,  
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we may distinguish between such as flow through valleys of uniform declivity without lakes, and such as pass through broad receptacles of water, before arriving at the sea. As examples of the former, we may take many rivers of England; for the latter case, several rivers of England, Wales, and Scotland might be named, but much grander phenomena of the kind are witnessed among the streams which flow down from the snow-crested Alps.

A certain velocity of current is requisite for the transport of every kind of earthy matter, the finer the matter the less force will move it along. Hence in the lower parts of rivers, where their course relents, as they approach the sea, though they can no longer, as in their youthful energy, remove rocks and transport loads of sediment, their waters are muddy, and their channels and sides receive continual augmentation. Such a river as the Yorkshire Ouse is very instructive. As its branches descend from Shunnor Fell, Cam Fell, and Wharfedale, they transport daily and hourly from those elevated sites the materials accumulated by atmospheric changes and mechanical attrition, the soil, the stones, the loosened rocks, grain by grain, and piece by piece, move onward with the current, and thus the whole mountain region, by a slow yet not imperceptible progress, is lowered in height, and its wasted spoils swept away for ever. But let us follow this process. Wherever the valley originally presented great inequalities, these are constantly diminishing by the upfilling of the hollows, and at length the originally rugged chasm is changed by *additions* and *upfillings* into the smooth, evenly declining hollow, which, because of that smoothness and uniform declination, is supposed by many to be entirely a valley of denudation. In this process, the lateral action of rains and inundations from the sides of the valley, is a very important auxiliary. Any one who contemplates the valleys of the Jura, near Schaffhausen, and sees them in many cases rugged on the sides, and evidently traced by nature in a fit of convulsion, must be struck by the smooth, even, equally declining *plane* of their bottom, which cuts the rude precipices of the sides, and clearly indicates a subsequent powerful modification of the original harshness of the chasm. Still more abundant is the deposit of sediment as the stream glides into lower ground. There, above its narrow channel, rise the broad meads which, with every fresh inundation, receive a new coat of sediment, and above these swell the real boundaries of the valley, often consisting of water-worn materials, gravel and sand, left there by ancient floods of greater power, flowing at a higher level. As we approach the sea, when the tidal currents meet the fresher, the suspension of motion permits a great part of what sediment still remains to discolour the water to drop on the bed of the river, and its alluvial banks. Thus the streams become choked, their channels sinuous, their beds elevated, and the banks which confine the river, heightened both by Nature and Art, look like the ramparts and terraces of a lofty military road rather than the boundaries of a river giving passage to the drainage of the neighbouring country.

The same process at the mouths of rivers, pushes their channel and their banks outwards into a cape or headland, and contributes to extend the whole breadth of the bordering coast, so that by the waste of the uplands the low land is filled up, the river-channels are raised, the coast is extended into the sea, and the sea filled with shoals and sand-banks. Thus the mouths of the Po, the Rhine, the Nile, the Euphrates, the Ganges, and the

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Mississippi, have formed for themselves those broad deltas which, within the Historic era, have transformed ancient ports into inland towns, and carried fertile pastures into the area of the sea.

The substances transported by the stream, and deposited along its sides, are of course such as the hills around its sources, and above its channel, furnish; and according to the nature of the country, the almost incessant accumulations of earthy matter which thus take place, may be varied by interposed layers of vegetable reliquiae. In tropical and warm regions, and in uninclosed Countries, this must be the case to a far greater extent than an acquaintance with European rivers would lead us to expect. The mighty forests of America, untouched by human industry, must annually furnish to the great rivers which intersect them, an immense spoil of trees, which being easily supported by the current, will be carried even to the sea, and either deposited at the river mouth, or drifted away on the waves.

Arrangement of materials.

The arrangement of the materials brought down by the streams is in general regulated by a tendency to the production of a level surface, and thus the original inequalities of a valley are continually lessened. In a high region like the Alps, the rough streams leave in the higher level chiefly a collection of pebbles and sand, and they are left in much local confusion; but still the general effect is a uniformly declining plane, through which the capricious stream finds itself new channels, and thus continually shifts its deposits over the whole, broad, pebbly surface. Such effects may be well seen on the line of the Arve, as it hurries down from the glaciers of Savoy. On the contrary, in the lower and more level expansions of a valley, where the gentler waters transport only fine sediment and vegetable reliquiae, these materials are arranged in most exact parallelism over a large extent of plane surface, and by counting the laminae of deposition, some useful notion may be formed of the period occupied in the process. On the borders of streams which are periodically swollen by rain, as in the Tropical regions, or by the melting of snows, as in those which descend from high mountain countries, this mode of computation of the laminae may even be trusted so far as to determine the number of years employed in producing a given depth of deposit; and even in districts where the rivers swell irregularly at uncertain intervals, there might be an *average rule* for the same purpose deduced. Nor would the accumulation of a short period of time, tried by this test, appear inconsiderable. In a single season, the rivers of Yorkshire, aided by the sea, deposit many inches of rich soil upon the level peat-moors which adjoin their estuary; and at Ferrybridge, at the point where the tide, formerly flowing up the river, neutralized the freshes of that river, many of the modern works of man, as oars of a boat, a coin of England, were found buried under the alluvial sediment, which contained petrified hazel-branches and nuts, bones of the stag, &c.

From what has been said of the action of rivers, it is evident that their effects upon the physical features of a country are more varied and interesting than has been generally perceived by those who have written on the much controverted question of the origin of valleys. The tendency of all descending streams of water is the same, to equalize the surface of the earth, to remove all its ridges and asperities, and to smooth all its gulfs and fissures.

The degree in which they respectively perform this

depends *first* on the amount of atmospheric and local influences in wasting the surface of the higher ground; and bringing materials for the rivers to act upon. Hence the rapid waste of high Alpine tracts exposed to fluctuating heat and cold, to storms, avalanches, and glaciers. Hence the streams of sand and pebbles which rush from the gritstone hills of England, and, on the contrary, the almost unsullied purity of the springs which break from the carboniferous limestone.

The *second* circumstance which determines the modifying power of the river is its own volume and velocity, and these are principally dependent on the physical geography of the region. The datum of the volume of water flowing in any valley is principally useful for comparison with the *amount of effects*; the *kind of effect* produced is determined by the *velocity* of the current.

If we conceive that in its first fury a river may have power enough to sweep along even large blocks of stone, but that its velocity gradually diminishes, there will be a certain point, where these large blocks will be left by the enfeebled current, pebbles will roll further, coarse sand will travel beyond, and the finer sediment will be moved on till the lagged waters permit their slow and equal deposition. This gradation of deposits is always observed in examining valleys of sufficient length and elevations. The deposits in the upper parts are tumultuous and confused, in the lower regions level and regular.

A *third* circumstance, of still more importance than the others, serves to regulate the action of the river. This is the *form and character* of the valley itself. However produced, there can be no question that the present aspect of almost every valley in the World, is smoother and more equalized than it was formerly, since we see evidently and take as a principle, that the characteristic effect of modern causes in action is to reduce continually the inequality which remains. We may, therefore, easily, for each valley, restore in imagination its ancient condition, remove the sediment from its expanded meadows, and leave, instead of level or gently sloping planes that wind smoothly round the hills, and ascend far up toward the sources of the stream, deep chasms between cliffs rent asunder by convulsion, and ridges of rock confusedly crossing the gulfs of the strata. That such has been the origin of many valleys, is perfectly evident. That these may have been partly cleared, and others wholly occasioned by violent floods, sweeping over and denudating the land during its elevation from the sea, or by some violent catastrophe at a subsequent period, is also very probable, or rather may be considered as proved. But without entering on these questions, we may content ourselves with the *datum* that the fundamental features of valleys are not the result of the excavating action of their streams, but that valleys have been in part filled up by the accumulations brought by their own rivers, and that their present smoothness and uniformity is really the result of the modifying powers of the atmosphere, local influences and the river, exerted through long time upon a ruder channel, left by more violent and transitory agents.

Let us now see what peculiarities in the effects of rivers are occasioned by the circumstance of their traversing quiet lakes. Two things are here to be attended to. First, the lake causes, according to its extent, a more complete deposition of the sediment brought by the rivers than is occasioned by the most level dry area of a valley; secondly, the materials dropped in

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the lake are regulated by somewhat different laws from those which direct their accumulation on the conical surface.

When a river charged with sediment expands into the waters of a lake, its motion, communicated to that large area in directions radiating from the place of entry, relents, and is almost lost, and the sediment which it brought is gradually and, at last, wholly deposited in the lake, whose transparency it disturbs, and the purified stream issues from the lower extremity without a single taint of its stormy origin, *unless it be the colour of the mountain-peat, or some other substance held in chemical solution.* Like the lake from which it escapes, or the ocean far from shore, it generally assumes the purest ethereal hue, its native tint of green or blue, but soon in its onward course it again becomes turbid with sediment. Every lake in Switzerland exhibits these pleasing effects upon the rivers, which commonly enter in turbid violence, and issue of a lovely transparent green, but the Rhone is pre-eminently blue. These lakes are filling and contracting at their upper ends with the sediment which they filter from the rivers, and the process, though historically slow, is monumentally impressive, since we perceive large tracts of level meadows cultivated, covered with trees, and adorned by ancient and modern towns, where formerly flowed the deep waters of the lake.

All this *new land* was formed from the spoils and waste of the upper Countries drained by the river, and it is an exact measure of the whole effect of the atmospheric and local influences in weathering the face of the hills, and of the rivers in transporting away the materials thus prepared for them *from the earliest period when the streams began to flow down the actual valley.*

The second thing to be attended to in considering the effects of lakes on the line of rivers, is the arrangement of the materials which they receive. This is a subject in which Mr. Yates's observations (*Edinburgh Journal*, 1831) will be found useful. It is known to practical men that loose earth will remain at rest if it be placed at an angle, not exceeding  $45^{\circ}$  with the horizon, and when loose, earthy materials are poured from a height, they usually arrange themselves in a conical heap, whose sides make nearly this angle with the horizon. On the slopes of mountains liable to avalanches or rapid waste, the loose debris is usually found in a plane declining at about this angle. When streams falling over an edge, pour with their waters a quantity of earthy matter, the conical heap so produced is very much more obtuse than when the materials fall dry, and the larger the proportion of water that comes down, and the more forcibly it descends, the flatter is the slope of the cone. This will easily be understood upon the principle that by partial suspension in water each particle is influenced by the tendency of that fluid to become level.

It is easy to understand from this that the form in which coarse sediment will be deposited by rivers entering a lake, must be in a very obtuse cone radiating round the point of entrance. As the heap of sediment is advanced into the lake by continual additions, its outline remains circular, with a larger radius, and its section will be nearly level toward the land, but sloping more and more rapidly toward the interior of the lake. Were the particles to be arranged in obedience to the double forces of horizontal movement with the river, and of perpendicular descent from gravitation, the curve of the edge would be parabolic, and

the surface left upon the sediment toward the land nearly level.

But the earthy matter being unable to support itself at more than a certain angle of elevation, the lower part of the curve will become less steep, and be reduced to a straight line. Mr. Yates's observations on the Swiss lakes led him to assign to the sediment left therein an outline of this kind.

It is obvious that in these cases the sloping layers nearest the entrance of the stream are of older date than those further advanced into the lake. It is an interesting subject of inquiry to learn whether, as is most probable, the particles of the sediment which differ in bulk and specific gravity, are arranged according to those qualities so as to constitute horizontal strata, of finer and coarser matter, &c.; and whether, this being the case, the sloping lines of deposition, &c. are visible or obliterated in the section. In this manner the upper ends of lakes are filled with the deposits from the rivers almost to the surface, and the dams of the lower ends of the lakes being worn away by the incessant action of the stream, these deposits become visible above the water, and constitute those smoothly declining, often moist surfaces, which usually confine within their indefinite border the shallow and weedy waters destined in their turn to retreat from the desiccated land. While this process proceeds near the shore with the coarser particles, it is obvious that the finer sediment will be carried further into the lake, and be spread more widely over its general bed.

These remarks apply only to deep lakes, whose waters rest tranquilly on their beds, and are only agitated at the surface. In shallow lakes, which are agitated to the bottom, the materials must necessarily be distributed in planes very nearly horizontal, in consequence of the impressions from the fluctuations of the surface. This is matter of daily observation.

Before we dismiss the subject of lakes, it will be proper to take notice of another process tending also to fill them with new deposits. Many streams which enter lakes carry along, dissolved in their waters, a quantity of carbonate of lime, which may afterwards, by the loss of carbonic acid from the water, fall in calcareous sediment, and constitute beds of marl, or by the slow absorption of mollusca be converted to shells. In the latter case, beds of limnaea, paludinae, &c. are formed, and as generally the light argillaceous sediment entering such lakes is pretty equally diffused through the waters, the result is a bed of marly clay full of fresh-water shells. This process is daily going on, and in the course of a few years canals and river courses, as well as ditches and ponds, are choked by the abundant accumulation. In this manner, aided by occasional inundations, bringing layers of vegetable matter, or the detritus of the neighbouring country, have many old lakes become entirely filled up, and when cut open for any purpose, present layers of peat, clay, shell, marl, and sand, a faithful image, on a small scale, of those great fresh-water deposits which mark the force and extent of ancient currents on the surface of the Earth.

The delivery of the sediment of rivers into quiet, tideless, land-locked seas is almost perfectly analogous to what happens in a large lake, but according to variation of circumstances, as the river flows into the open ocean, and contends with strong tides and sweeping currents, or disembogues itself into a gulf, enters deep or shallow water, the disposition of its sediment is dif-

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ferent. The most remarkable deltas at the mouths of rivers are formed round such as empty themselves into tideless seas, as the Mediterranean, Black Sea, Caspian, Baltic, &c., or into comparatively quiet bays of the ocean, as the Bay of Bengal, the Gulf of Mexico; and the least effects of this nature are occasioned on coasts which are subject to be raked by lateral currents of the sea.

Most of the great rivers which enter the Mediterranean are daily increasing their deposits along the coasts, and spreading a quantity of sediment over the general bed of the sea. The Mediterranean has been proved by a line of soundings on the Skerki shoal from the African to the Sicilian coast, varying unequally from 7 to 91 fathoms, to be divided into two basins. In the Western portion, near Gibraltar, the bottom, consisting of sand and shells, has been reached at 5880 feet, and in the Straits at 4200 feet. Almost under the shore at Nice the depth is 2000 feet; but in the Adriatic, where it receives the sediment of the Po and other rivers, in the upper part, the greatest depth is 22 fathoms. Yet from the abrupt borders of the hill ground within the area of the sedimentary land, it is inferred that the Adriatic must formerly have been a deep gulf.

Nature of  
the deposits  
in gulfs, es-  
tuaries, &c.

Further from the influence of the rivers the depth increases considerably. Donati, on dredging the bottom of the shallow portion of the Adriatic, found it to consist partly of mud, and partly of calcareous rock, enclosing shells, which are sometimes grouped in families. (Lyll, 237.) The form of these sedimentary deposits must be what in common language is called horizontal, the substance of them fine clay and calcareous matter with shells, and as the ratio of accumulation is nearly uniform, there will be little appearance of strata, unless the calcareous deposits be accomplished at intervals. If by any effort of subterranean forces this bed of the Adriatic should hereafter be elevated, and made dry land, as so many other extensive tracts along the borders of the Mediterranean have been, we should have an argillaceous deposit extremely similar to the London clay, and perhaps identical with the subapennine marls, except by some difference of organic remains, and of such an extent as would appear incredible to those who believe in the almost quiet slumber in modern times of the mechanical and chemical forces which belong to our Globe. The same conclusions might be derived from an examination of the mouths of the Rhone, Volga, Danube, Ganges, Euphrates, &c. which enter the sea under the same favourable circumstances, and transport enormous quantities of fine sediment into comparatively tranquil and now shallow waters. A river like the Mississippi, which hurries an enormous volume of deep waters, and preserves its velocity to the edge of the sea, discharges likewise a prodigious quantity of matter, which settles round its many mouths into a vast and growing delta. But the kind of matter here deposited, and the mode of its arrangement will be different. Forests matted together by the growth of Ages, with all their foundations, their alligators, and other inhabitants, are swept down by this mighty stream, and either retarded for a time among its winding and variable channels, or hurried into the sea, and there, with quantities of similar matter, agitated, and partially or completely separated into beds of earthy and vegetable matter, the latter varying according to the prevalence of the many rivers which unite in the great stream, and thus the Gulf of Mexico is now filling with deposits, which in no feeble degree

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emulate our old carboniferous strata. We are informed by Mr. Lyell, whose volumes are full of valuable information on all subjects connected with the modern operations of natural agencies, that a great part of the new deposit at the mouth of the Rhone consists of calcareous and arenaceous-calcareous rock, containing broken shells of existing species; and Captain Smyth ascertained that over the broad, very gently inclined bed of this growing delta, marine shells were occasionally drifted by a South-West wind. In this way alternations of fresh-water and marine shells may be occasioned, in which the marine portions will predominate towards the sea and the fresh-water part be most decided toward the land.

The shorter and more rapid the course of a river, the larger and coarser is the sediment which it may be able to transport. While the Po, relenting in its velocity, leaves its gravel where it joins the Trebia, West of Piacenza, 130 miles from the sea; and the Ganges 180 miles above the commencement of its delta, and 400 miles above the present line of coast; the rough bed of the Yorkshire Tees is pebbly quite down to the sea; and the streams which descend by a short and furious course from the Maritime Alps bear down pebbles into the Mediterranean.

From these instructive examples of pebbly, sandy, argillaceous, and calcareous strata, forming at the same era, in different basins of the sea, and even in different parts of the same basin, enveloping entirely marine, entirely fresh-water, or a mixture of marine and fresh-water deposits, we may turn with advantage and pleasure to the contemplation of the older strata of conglomerate, sandstone, clay, marl, and limestone, and by carefully noting the points of agreement and circumstances of difference, may frame very satisfactory notions of the conditions under which they were deposited respectively. Especially we may be guided in our decision concerning the extent and connection or separation of the several basins of the ancient Ocean, and the relative influence of ancient and modern rivers.

Rivers which discharge themselves into the sea, where tides and currents contend with the freshes, may, as the Rhine, be enabled for a certain time to deposit their sediment in a Delta, and to increase this even to a vast degree, in consequence of their entering at a deep emargination of the coast, or amidst shallow sands which impede the action of the tide. But in such a case, the accretion of land must gradually diminish, and at length the movements of the sea must balance the current of the river. In this case a line of sand-banks will be formed varying in position according to the alternate predominance of the contending forces, and the entrance of the river will have a bar. The Rhine, the Thames, and all the Eastern rivers of England are nearly in the same case. The sea, indeed, has again reclaimed from the Rhine, by most destructive floods, the large spaces of the Zuyder Zee and the Bies Boos.

Thus also the growth of the Nilotic Delta, once so rapid, is greatly retarded or almost annihilated by a current of the Mediterranean; and the rivers of Western Africa, as well as the mighty Maranon, no longer extend themselves into the sea, but meet its currents in furious strife, drop the sand at their mouths, and resign their finer sediment to the disposal of the conqueror. The distance to which the Ocean can waft this sediment on its surface along with fresh water is very great. Captain Sabine supposes himself to have crossed the

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discoloured waters of the Maranon 300 miles from its mouth, where it still retained its comparative levity, and kept its place on the surface of the sea.

Thus may the sediments of distant Countries be mixed or alternately deposited far from shore, and even in the deep sea, a fact of great interest to Geology. The distinctness of currents of water which flow down the same river channel, even with a rapid descent, has often been noticed. Thus the Arve and the Rhone flow far without mixing, the Nahé takes one side of the Rhine, and even in the mining districts of England, the discoloured streams from the different valleys can often be distinguished along considerable lengths of the united river.

We shall not further extend our remarks on this subject than by stating a few instances of the actual surface of the Deltas of great rivers. The whole area of the dry Delta of the Po and the Adige, and other rivers which contribute to the effect on the same line of coast, must exceed 2000 square miles, and within the last 2000 years a space of 100 miles in length, and from 2 to 20 miles in breadth, has been added to the land. The area of the Nilotic Delta is about 12,000 miles, and according to Girard the surface of Upper Egypt has been raised by the sediment since the Christian era 6 feet 4 inches; of the Rhone 1500 square miles; of the Quorra 25,000 square miles. (Dr. Fitton, *Geology of Hastings*.)

The Delta of the Ganges, without reckoning that of the Brurampootra, which has now become conterminous, is considerably more than double that of the Nile, and its head commences at a distance of 220 miles in a direct line from the sea. The base of this magnificent Delta is 200 miles in length. (Lyell.)

The fen lands of Lincolnshire, Huntingdonshire, and Cambridgeshire occupy 1000 square miles, and the levels in connection with the Humber 300 or 400.

It has been attempted to deduce the age of our continents for the rate of increase of the Deltas of rivers within the Historic era. Thus the Nile was supposed by Herodotus to have formed Lower Egypt; and he states that if diverted into the Red Sea, it would fill that gulf with its deposits in less than 20,000, or even 10,000 years. Since the time of Herodotus it is supposed that the increase on the Nilotic Delta has been upon an average, one mile and a quarter. The average annual growth of the Delta of the Po, opposite Adria, which was once on the edge of the Adriatic, was, from 1200 to 1600 A. C., 25 metres, and from 1600 to 1800, 70 metres; a very rapid increase of rate, probably connected with the increasing shallowness of the sea. (Lyell, *Principles of Geology*.)

But all inferences from observations of this nature, and similar ones on the shallowing and conversion to land of the upper ends of lakes, can lead only to merely speculative results without the knowledge of a datum very difficult to be obtained, viz. the original depth of the sea, at all points over which the river sediment has flowed; for it is not by the area of the Delta, but by the cubic content of the sediment transported that the time occupied in the process is to be ascertained. How is this to be determined?

The Sea.

As the action of rivers is of two kinds, erosive and transporting, so is that of the sea. In one place its fury excavates the cliffs, and devours a whole country, in another every tide adds sediment to a growing shore, lengthens the fields, and extends the parishes, till what was once a broad bay becomes a fertile marsh, and the

town which was once a flourishing port is far removed from the waves, and never visited by commerce. These different effects depend principally upon the circumstances under which the earthy materials are presented to the waters. Cliffs exposed to the sea are either slowly decomposed by its vapours, and crumble piecemeal, or undermined at the base, and so caused to fall in ruinous heaps. Even the hardest rocks that begird the Ocean are more or less wasted away by its never-ceasing attacks, conjoined with the common atmospheric agents. Soft places are scooped into caverns, joints are widened, and blocks loosened, and thus, by little and little, every high coast recedes and yields more or less ground to the insatiable waves. But cliffs composed alternately of softer and harder strata, especially if there be any dislocation, are quickly eaten away, and still more rapid destruction falls annually on the crumbling diluvial clays and loose gravelly cliffs which margin so great an extent of the coast of England. The whole of the English coast may be cited for cases of this important wasting of the cliffs, and in particular the diluvial cliffs of Yorkshire and Norfolk. In the former County it seems to be ascertained, by careful measurements at many points, repeated after intervals of many years, that the annual loss of land on the whole length of Holderness, is not less than 2 yards in breadth annually. The average loss on the coast of Norfolk between Weyburn and Theringham is about 1 yard per annum, on the coast of Thanet 2 or 3 feet. But these same coasts likewise exhibit, on an equally grand scale, the formation of *new land* from the materials thus detached from the old. The materials which fall from the cliffs are sorted by the tide, and according to their bulk and weight are differently disposed of. As in many artificial processes of washing powders the sediment is divided into parts of different fineness by merely shaking it at different distances or depths in the stream of water, so it is in the great currents of the sea. Large stones remain a long time at the foot of the cliff from which they fell, smaller masses yield something to the impetus of the waters, sand and pebbles are drifted along the shore according to the set of the tide, and collected into bays and hollows of the coast, or deposited in a line of moving beach; but the finer clays are transported far away in the waters, and allowed to settle only where these rest in land-locked gulfs, stagnate over weedy marshes, or lose their force in contest with the freshes. The breadth of the sandy beaches thus accumulated is often very great, even many miles of slow and regular descent. The sand-banks which stretch out so far from the low coasts are often regarded as remains of ancient lands overwhelmed by the sea, but in most cases they are probably recent formations, accumulated by the waves from the spoils of other regions. But what is thus left by the sea under some circumstances, may be again reclaimed by it under others. The once fertile district called North Friesland, most probably accumulated by the sea, measuring from nine to eleven geographical miles from North to South, and six to eight from East to West, was in 1240 entirely severed from the continent, and in part overwhelmed. The Island of North-strand, thus formed, was, towards the end of the XVIth Century only four geographical miles in circumference, but still was richly cultivated and populous. At last, in 1634, in one night, the 11th of October, a flood passed over the whole island, whereby one thousand three hundred houses, with many churches, were lost, fifty thou-

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sand head of cattle and above six thousand men perished. Three small isles alone remain, and they are still further wasting. (Lyell.) It may often be remarked that substances thrown into the sea are not carried down at once to its depths, but rejected many times to the shore, in the direction of the tidal currents. This happens especially with all light, small, and easily moved bodies; but the case is different with the large blocks of stone, which, continually pressing by their weight downwards, are for the most part gradually withdrawn from the base of the cliff sunk in the beach, and rolled down to the deep.

In this manner, when the circumstances admit of it, the whole coast is in motion, every high cliff wastes away, the low grounds stretch out, the beach widens and again contracts, shifts upwards and downwards, and travels along, and thus amidst the extremes of constant fluctuation and change, new deposits are continually added to the quiet depths of the sea, and to the lowest parts of the land. As far out as the fluctuations of the waves can influence the bottom of the sea, the new deposits, where uninfluenced by currents, must become nearly horizontal; in greater depths it seems reasonable to suppose that the materials will be arranged nearly as in deep lakes; and under the cliffs, the beach being only at intervals exposed to the rush of ascending and descending waves, must have its surface inclined at corresponding angles.

We have no accurate data on which to found an opinion concerning the utmost depth to which the influence of the superficial undulations of water may extend. The influence of the tidal and other currents of the sea must extend to a great depth, and tend to equalize into nearly horizontal strata the loose materials collected from the waste of the land.

Coral  
islands, &c.

These extensive deposits of sand and clay are, however, not the whole of the productions of the sea. The Ocean indeed is but a large lake, and, besides the mechanical effects on its borders, is subject to various chemical changes, and to the unceasing agency of the functions of Organic Beings. Into that vast repository there flow annually great quantities of soluble matter of various kinds, and it is quite conceivable that by the interchange of their elements some chemical deposits may happen. It is also not unreasonable to admit that many exhalations rising from the bed of the sea may cooperate in such effects. But there is one ascertained cause incessantly in operation which probably occasions more extensive and permanent precipitation of carbonate of lime than any other process, the growth of zoophyta, shells, and crustacea. However small may be the quantity of calcareous matter suspended in water, the molluscons and zoophytic animals, which require such matter for their stony supports, are sure to possess themselves of it; and as corals and shells remain when their tenants dissolve away in the water, the bed of the sea is continually receiving important additions from this source alone. Besides these, the cast shells of crustacea, the teeth, and sometimes the skeletons of fishes and cetacea, must

contribute no mean quota to the growing stock. It is perhaps yet an undetermined question to what depths in the sea light and the vital influence of the atmosphere can sustain the growth of plants and animals. We may, however, safely believe that the extreme gulfs of the sea are as devoid of organic life as the central solitudes of a sandy desert, while the borders of the one, and the shores of the other, teem with innumerable forms of life.

It was formerly supposed that those immense reefs of coral which divide the waters of the Pacific Ocean, and rear themselves above the waves into associated islands, arose from the deepest parts of the sea, in perpendicular walls. But many observations by Captain Beechey and other navigators, upon the crater form which the coral islands generally assume, and the volcanic rocks upon which they are frequently based, have produced a very general impression that the polypcean races do not exist except at moderate depths. Captain Beechey found the coral of Ducies Island to be forming at a depth of one hundred and eighty feet.

The quantity of carbonate of lime thus produced by the coral animals, with the addition of shells, &c. enveloped by them in their progress, is really enormous, and might almost justify those Geologists who think that our stratified limestones are wholly derived from comminuted shells and zoophytes. A great proportion of all the low islands in the South Pacific Ocean is the work of zoophytes, and new islands are daily in progress, and submarine reefs of so great extent that Captain King found a continued line of coral reef 700 miles in length, from the North-East coast of Australia towards New Guinea. It was interrupted only by a few intervals not exceeding in the whole 30 miles in length. These reefs consist in great part of compact limestone, and Mr. Lyell compares them to the ancient calcareous rocks of the basins of Europe and North America.

This comparison, so just as to quantity of material, must not be extended to the structure and arrangement of the several masses. The rocks of carboniferous limestone have indeed derived a large part of their materials from the calcareous secretions of polypcean and molluscons animals; but the materials can have been put into their present stratified form only by the ordinary mechanical action of water upon them. A modern coral reef might, by long movement in water, be ground up into something like a limestone bed, but the sharpness of the angles of the ornamented fossils of all the old calcareous strata appears to disclaim such an origin for these rocks. At the same time it is to be observed that the corals and other zoophytic reliquiae, which abound in some of our limestones, very seldom appear to be in their ordinary places of growth, but rather seem to have been subject to some drifting. The corals may therefore in ancient times have grown in reefs, as at present, and this may perhaps be the reason of their irregular and unequal dispersion in the rocks—a fact particularly remarkable in the coralline oolite.

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## CHAPTER III.

## DESCRIPTION OF THE ROCKS PRODUCED BY IGNEOUS AGENCY.

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IN the preceding Chapter we described the series of aqueous deposits which contribute to form the crust of the Globe, commencing our account with those of the earliest date, and terminating it with the consideration of the most modern.

In the present Chapter a similar order cannot be observed, inasmuch as in the case of the igneous formations which it becomes our next business to consider, we do not possess those criteria, derived from the order of superposition, and the nature of the imbedded fossils, by the aid of which we were enabled to determine in the former instance the question of relative antiquity.

Neither, indeed, are we entitled to take for granted *in limine* the igneous origin of all the rocks which will fall under our review, seeing that some of them have, until very recently, been attributed to causes of quite a different character, and that even at the present day they are regarded by some Geologists as of questionable formation.

It will be more satisfactory, therefore, in the present Chapter, to reverse the order of arrangement adopted in the preceding one; considering in the first place those operations of an igneous description which are going on in the interior of the Earth at the present day, tracing the effects which have arisen from similar causes operating during the historical period, and thus gradually ascending to the consideration of such apparently analogous phenomena, as may seem referable to those same agencies, acting at a still more remote era, and under circumstances in some respects different.

In this manner, we shall be best enabled to pronounce upon the origin of such rocks as deviate too widely from the structure and constitution of the products of igneous action which we see at present forming, to be referred at once and without examination to the same cause, and which, whatever may be their exact date, are at least not seen to be produced by causes now in operation.

Proceeding, then, from the known to the unknown, referring in the first instance all that is possible to existing agencies, and preferring to explain the remainder, by assuming a greater intensity of the same forces, rather than the influence of others of a different kind, we shall consider it our primary object to treat of volcanos at present in action; these being confessedly the most powerful and widely diffused of the igneous agents which are at work.

We shall therefore inquire, what phenomena, observed to take place under present circumstances, may reasonably be attributed to such a cause; and if it should appear, that all the changes of any importance going on on the Earth's surface which remain to be discussed, may without difficulty be referred to its agency, our task will then be greatly simplified, inasmuch as it will be limited to the consideration, in the first place, of existing volcanos and their consequences, and secondly of those which are extinct; after which we shall proceed to inquire into the nature of those granitic rocks and of others, which have protruded themselves, at different, though

always at epochs antecedent to the present, through the aqueous deposits which compose the crust of the Globe.

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## PART I.

ON ROCKS PRODUCED BY IGNEOUS OPERATIONS  
OF A SIMILAR NATURE TO THOSE NOW  
TAKING PLACE.

## SECTION I.

*Description of Volcanic Phenomena in different Parts of  
the World.**General Notion of Volcanic Action.*

If we contemplate a volcano whilst in a state of vigorous action, the phenomena presented to us are at once so peculiar and so impressive, that it would seem unnecessary to be at the trouble of defining that, which the commonest observer could hardly fail to recognise again, in whatever part of the Globe it might fall under his observation.

The evolution of smoke and ignited matter from an orifice in the Earth, generally situated on the summit or flanks of a conical mountain, the ejection of fragments and scorix, bearing a near resemblance in their condition and aspect to the slag of an iron foundry, the sudden and copious extrication of elastic fluids, with their natural concomitants, noise and a concussion of the rocks through which they force their way, are circumstances which strikingly impress upon the imagination the paroxysms of volcanic action, and appear to distinguish this from all the other operations of Nature.

Accordingly from the earliest periods the existence of volcanos had excited attention, and their leading phenomena were pretty correctly described. They have supplied a groundwork for the superstitions of the vulgar, and for the speculations of the philosopher, and much of our present knowledge with regard to the character, extent, and date of their operations, may be collected from the incidental notices of them, transmitted to us by the Historians, and even by the Poets of antiquity.

Nevertheless, when we examine the subject more attentively, difficulties occur with respect to the real relation borne by them to several of those phenomena, which from some obvious feature of similarity have been regarded as their offspring.

It, in conformity to the vulgar idea, all *burning* mountains are ranked amongst volcanos, we admit into the same class a variety of incongruous appearances, which possess indeed no one character in common, except that of being accompanied, with what seems at least to be an emission of flame, and which are therefore assignable in all probability to causes of many different kinds. If, on the contrary, none, but such as present this obvious resemblance to existing volcanos, are to be included in our definition, we lose the advantage of considering a series of effects, evidently allied to the subject before us, and perhaps equally illustrative of its real nature.

How different, for example, are, the eruptions of Vesu-

vius and Etna, in *kind* as well as in *degree*, from the emanations of gas and aqueous vapour, which proceed at times from the sulphureous soil at Macaluba in Sicily, from the foot of the Apennines near Modena, and still more remarkably, it is said, in Crim Tartary, and in the neighbourhood of the Caspian; or from the emissions of gas now observed at Pietra Mala, between Bologna and Florence, and the spontaneous fire (as it was believed to be) which in ancient times added to the superstitious reverence entertained for the sacred peaks of Parnassus.

On the other hand, if we consider the character of the phenomena exhibited, how intimate is the connection between the eruptions of Vesuvius and the earthquakes or hot springs in its vicinity; and, looking only to the nature and constitution of the mineral products, how impossible is it to draw a line between those which have *evidently* resulted from its eruptions in modern times, and many rocks in the contiguous country, where nothing of a volcanic nature has as yet been noticed as occurring.

#### *Phenomena attributable to Volcanic Action.*

In order, therefore, to establish a sufficiently broad basis on which to ground any general conclusions with regard to the agency of this cause throughout Nature, it seems necessary to settle in the first place, what phenomena, independently of those more palpable ones which first occur to the imagination, are to be regarded as indicative of volcanic action, exerted under the same circumstances as at present, though, possibly, at a very remote period.

It is clear, that the date of the eruption, which gave rise to these effects, will be immaterial to our present purpose, provided we possess an equal certainty as to its reality: and we shall be entitled to avail ourselves of the evidence to be derived from extinct as well as existing volcanos, just as the traveller, who should endeavour to collect proofs of the existence of iron foundries in an unknown country, might be at liberty to infer their presence, not only in places where they were at the time established, but also wherever such accumulations of slag and scoræ were found, as could only have arisen from the same formerly in operation.

#### *Phenomena admitted to be Volcanic.*

Now the circumstances, which may be held sufficient to substantiate the existence of volcanic operations, of a description similar to those now proceeding, are derived from three sources:

1. Indications of internal commotion; manifested in the ejection of heated stones and scoræ, the emission of lava currents, and the evolution of aqueous vapour, together with certain gases hereafter to be described.

2. The structure and appearance of the masses taken collectively; namely, the existence of a mountain approaching to a conical form, and composed either wholly, or at least superficially, of strata, possessing what is called a quaquaversal dip, or sloping away in all directions from a common centre, where some vestiges at least remain of a crater-shaped cavity.

3. The condition of the individual rocks themselves; namely, the presence in them in a greater or less degree, of a vitreous aspect and cellular structure, with a corresponding chemical constitution, in which some of the combinations of silica with the alkalis and alkaline

earths form the prevailing, or, at least, the most constant ingredients.

Now we have no evidence, that either the mechanical or chemical characters above described have ever resulted from aqueous solution, whilst both the one and the other are familiar to us, as the effects, not only of volcanos, but also of artificial heat.

Without, however, pretending in this stage of the inquiry to assert, that the constitution of the mineral masses above assigned is sufficient in itself to establish the action of heat, we may be justified in concluding, that where it is conjoined with the cellular structure and glassy aspect alluded to, it may fairly be assumed to owe its origin to volcanic operations. In many, indeed, of those of modern date, the cooling appears to have been too rapid, to allow of any crystalline arrangement of the constituents taking place; and in a still larger proportion, though numerous crystals of augite, hornblende, and other minerals, may be disseminated, yet the basis of the rock cannot be identified with any known mineral or mixture of minerals, though apparently made up of augite and felspar in various proportions, and consequently presenting all shades of colour from grey to black. In these cases, the vitreous character, which more or less completely belongs to the rock, is sufficiently conclusive as to its origin, but the mineral composition can only be inferred from analogy, at least by common observers, who want either the patience or adroitness to adopt the mechanical method of examination, by which M. Cordier, it is said, contrives to separate and distinguish minerals too intimately blended to be recognisable by the eye or the lens. Indeed, the very employment of this method presupposes a certain confused crystallization, and is, by M. Cordier's own confession, inapplicable to many volcanic products, which, after having undergone fusion, were placed under circumstances precluding any new arrangement of the particles from taking place. Yet, wherever this is not the case, or what, practically speaking, comes to the same thing, wherever the component minerals are not too much blended together to be determinable, we generally find, that the basis of the rock is of a felspathic nature, rendered porphyritic by the presence of crystals, either of the glassy variety of felspar, or of some mineral of the hornblende or pyroxenic families.

The presence of the two latter, in sufficient quantity to impart their characters to the mass, stamps it as belonging to that class of volcanic products which has been denominated basaltic, and distinguishes it from the more purely felspathic kind, in which such ingredients are only of scanty and partial occurrence.

The latter class of ignigenous products, which consists for the most part of compact felspar, with crystals of glassy felspar imbedded, (owing to the harsh and gritty feel belonging to most of its varieties,) has been denominated trachyte, from the Greek word, (τραχυς, rough;) it has been observed by Von Buch and Humboldt to form, as it were, the basis of many existing volcanos, and even constitutes the material of certain lavas apparently of modern formation.

Amongst extinct volcanos, many entire mountains, and even vast tracts of country appear to be composed of this rock, which, whilst it passes on the one hand into clinkstones and phenolites similar to those occurring in the trap formations, graduates on the other into the species of volcanic products above alluded to, in

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proportion as crystals of augite and hornblende begin to be superadded to those of glassy felspar, which are essential to it.

The second class of volcanic products, distinguished by the predominance of these minerals, has been denominated by Mr. Scrope *greystone*; and as this term has a more English cast than the corresponding one, *tephrine*, which M. Brongniart had imposed upon rocks so constituted, it may be convenient to adopt it.

The greater part of modern lavas, whose constitution can be made out, appear to be composed of this species of rock, which is of course divided into a number of varieties, by the presence of sundry accidental ingredients, such as olivine, mica, titaniferous iron, and the like. In one or other of these classes, all volcanic rocks may probably be arranged which possess any discernible mineral structure; and those, in which fusion and rapid cooling has obliterated all traces of this kind, may nevertheless be referred with some degree of probability to one or the other.

Thus the pearlstones and the white pumices appear, from their chemical composition, as well as their external aspect, to be derived from trachyte; the absence of the materials of augite and hornblende being evinced from their not containing iron; whilst the obsidians and the lithoid lavas generally partake of the character of greystone, the proportion of *oxide* of iron serving to show (even where their mineral structure is undiscernible) that augite has contributed to their formation. The same remark, indeed, applies to the case of *basalts*, properly so called; and the difference of structure which is discernible in passing from the obsidians to the true basalts, between which the different varieties of modern lavas seem to be, as it were, the connecting links, indicates, that they have been all derived from some common matrix, which, after having undergone fusion, had cooled under different circumstances.

The only exception to this, is the larger quantity of alkali present in certain obsidians than in basalts and lavas; a circumstance which may, perhaps, enable us to explain, how it happens that this mineral, which we are disposed to attribute in general to sudden cooling, shall nevertheless be found occasionally to constitute streams of considerable size and thickness, where we might therefore expect lithoid lava to have been produced.

The rocks above noticed may each of them exist under several different modifications of form and aspect; they may occur, either as loose, detached blocks, ejected, probably, in a solid, or, at least, a semi-fluid state from the crater, or as the constituents of a kind of tuff; fragments of various sizes being imbedded in a sort of loose iron-clay or sand, denominated *puzzolana*; or, lastly, they may constitute a bed of lava, which once issued in a continuous stream from the interior of the volcano, whilst in a state of vehement activity.

To give to such materials in all the above cases the name of *lava*, as some Geologists have chosen to do, is obviously incorrect; this term having reference, properly speaking, not to the particular constitution, chemical or mechanical, of the mass, but to the mode of its ejection from the volcano; and being, therefore, improperly applied to rocks which appear to have been projected in detached fragments into the air, and never to have formed part of a current of melted matter.

We likewise coincide with Mr. Scrope in condemning the limitation of the term *trachyte* to felspathic rocks of a particular age and position, thus excluding those lavas

which possess corresponding mineral characters. That rocks agreeing altogether in mechanical structure and aspect with the trachytes of tertiary formations are uncommon amongst the older rocks, may, indeed, be true; but to lay down as a rule that the porphyries of one particular age are alone to have this title, is to prejudge the question, and to proceed on quite a wrong principle in framing our nomenclature.

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#### *Division of Volcanic Products according to their relative Ages.*

Volcanic products have been distinguished by some Geologists according to their relative antiquity; those which appear to have been ejected antecedently to the period of the excavation of the contiguous valleys being denominated *antediluvial*, and those of subsequent ejection *postdiluvial*. Others have objected to this distinction as involving an hypothesis; since, as we have seen, it is still a question of debate whether valleys of denudation have been produced by short periods of general convulsion, or by the continual operation of rains and torrents, acting with only their present force and violence. Perhaps, however, the terms may still be admitted by Geologists, of whatever school, with the same mental reservation, as that, with which many have been in the habit of employing the corresponding ones, of diluvial deposits, diluvial gravel, and the like. They serve to distinguish the relative antiquity of the rocks so classified, with greater precision than the terms of *ancient* and *modern*, which it has been proposed to substitute, since they refer to a definite standard, which leaves no doubt in the mind as to the sense in which we employ the word antiquity in our Geological language.

Without some such understanding, indeed, the volcanic rocks in Auvergne might be called *ancient*, with reference to those of the Vivarais, though they are modern when compared with others in their own neighbourhood; whilst in either point of view they must be regarded as *postdiluvial*, since their relation to the valleys of the country is such, as to prove, that no great changes have taken place in the configuration of the surface, since they were ejected.

Even if it be true, as Mr. Scrope contends, that there are lava currents in some of these volcanic districts, as in Auvergne, which appear to be antecedent to some of the valleys of the country, and posterior to others, there will still be nothing to preclude us from applying the above denomination to cases in which this cause of uncertainty does not exist.

#### *Postdiluvial Volcanic Rocks.*

Now the importance of distinguishing the relative ages of volcanic rocks, in the manner above proposed, will be evident from considering, that the two classes commonly differ one from the other in aspect and structure. The *postdiluvial* volcanic products having, in almost all the cases in which they come under our examination, been ejected in the open air, and, consequently, for reasons which will be afterwards explained, having in general cooled more rapidly, present for the most part a harsher feel and more of a vitreous aspect; whilst from the character of their component masses, even more perhaps than from the shorter period, during which their surfaces have been exposed to atmospheric action, they are but partially covered with soil, and admit, consequently of but a scanty and inferior pasturage.

For the same reason, they consist more commonly of those volcanic products, in which the constituent parts are blended together so as to be undistinguishable, though from their general appearance, and from the character of those portions in which the mineral composition may be discerned, it would appear, that basaltic lava or greystone predominates over the purely trachytic, in those modern volcanos with which we are best acquainted.

#### *Antediluvial Volcanic Rocks.*

The antediluvial volcanic rocks, on the contrary, are not only characterised by valleys of precisely the same kind as those which intersect the contiguous country, but likewise, by a greater tendency to crystallization in their constituent parts, by a greater predominance of felspar, by the occurrence of masses sometimes in no way distinguishable from the basalts and greenstones of the trap formations, and still more frequently exhibiting a nearer approach to them, than is observable amongst the products of igneous action at the present day. Though frequently cellular, their cells have not that glazed internal surface which characterises many modern lavas, and are usually more or less completely filled with crystals of carbonate of lime, zeolite, and other minerals, which are not so frequently found amongst postdiluvial lavas.

What variation in the circumstances under which the former were ejected could have given rise to these differences, will form a subject for future inquiry: at present it is only necessary to point them out, as a reason for distinguishing volcanic rocks into two classes according to their relative antiquity, those ages being determined, either by their shaping their course in conformity to the present configuration of the country, or being themselves intersected by the so called valleys of denudation. The opinion which may be entertained with regard to the origin of such valleys, will not materially affect the question as to the propriety of availing ourselves of such a distinction; since the vast difference, between the width and depth of the valleys which in many cases intersect the older volcanic rocks, and that of the ravines which evince the action of existing causes upon the modern, proves, that if the same agencies, operating with their present intensity, have produced the former, it can only have been after a lapse of ages beyond comparison greater.

In Auvergne, for instance, where the most modern volcanos appear to have been anterior to the Christian Era, the utmost amount of the excavation effected in them by present causes, is to produce a ravine or water-course, in some instances, indeed, as much as from fifty to seventy feet in depth, but still of very inconsiderable breadth; whilst the ancient volcanic rocks are characterised by valleys possessing the easy and gradual slope of those which belong to the older rocks of the country, and like them, often many hundred feet in depth, and perhaps a mile or two in diameter. Another important distinction in the character of volcanic products, depends upon the situation of the point in the Earth's crust on which the eruption breaks out, and in particular upon its occurrence either in the open air or under deep water. We say, deep water, because in shallows no great influence could be expected to be exerted, and the phenomena would therefore resemble those which take place in air. But, between the nature of products arising from the same volcanic action, under the pressure of only one, or

of a thousand atmospheres, considerable difference might be anticipated; and hence it becomes proper *in limine* to mark the distinction designating the former class of volcanos as *subaerial*, the latter as *subaqueous*. The characters of these two classes will be considered afterwards; but in the first place we will proceed to give a brief description of the principal foci of volcanic action distributed over the face of the Globe, conceiving, that by so doing, we shall enable our readers to obtain a better notion of the general character of the phenomena themselves, than could be gathered from any more abstract account of them.

We shall, therefore, begin with the vicinity of Naples, not only as supplying us with one of the longest known, and best described instances of volcanic agency that exist, but likewise as exhibiting these phenomena under all their various phases of activity, contrasting the effects produced in earlier periods of the World with those going on at the present.

#### *Vesuvius.*

To the East of the Bay of Naples rises the most recent of the volcanos, and with in that neighbourhood, and the only one at present in complete activity.

The date of that part of the mountain properly called Vesuvius, or rather of its cone, perhaps does not go further back than the period of the famous eruption of A. D. 79, in which Herculaneum and Pompeii were destroyed; for the ancient writers never speak of the mountain as consisting of two peaks, which they probably would have done if the Monte Somma had stood, as at present, distinct from the cone of Vesuvius.

Other facts might be also mentioned to show, that the old mouth of the volcano occupied the spot now known by the name of the Atrio del Cavallo, but that it was greatly more extensive than that hollow, comprehending likewise the space now covered by the cone, which was thrown up afterwards, in consequence of the renewal of the volcanic action that had been during so many ages suspended. This spacious crater was probably the spot in which, according to Florus and Plutarch, Spartacus and his Gladiators were besieged by the Roman General Clodius Glaber.

We infer from the account given, that the brim of the crater was entire, except in one part, by which the insurgents had entered, and which the enemy kept closely guarded; and the great steepness of its sides is evinced by the scheme which the besieged party were compelled to adopt in order to effect their escape; that, namely, of twisting into ladders the vine twigs that grew upon the top, and descending by means of them to the bottom, where they surprised the Roman Camp. Nor does this seem inconsistent with the account given by the accurate Strabo respecting the structure of Vesuvius in his time; namely, the fertility of its sides, and the barren flat which constituted its summit; this flat being in all probability the spot occupied by Spartacus, broken away on the side fronting Naples, but encompassed elsewhere by steep precipices, the relics of the original brim of its crater.

It appears then, both from the silence of ancient writers, and from the appearance presented by the mountain itself, that a long interval had elapsed since any indications of activity had been observed; and the first symptom of internal agitation given by the volcano was in the year 63 after Christ, when an earthquake



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occasioned considerable damage to many of the cities that had been built in its vicinity. But it was not till the year 79, that the first eruption of Vesuvius took place, of which any historical records exist. It overwhelmed the cities of Stabiae, Pompeii, and Herculaneum, with showers of sand, pumice, and lapilli, and seems to have covered the latter to a still greater depth with a kind of mud eruption similar to those which are produced, not unfrequently, by the volcanos of South America. Such, at least, is the inference that has been drawn from the circumstance, that the former towns are covered only with strata of incoherent materials, little, if at all, affected by water, whilst the latter is buried in a kind of tuff, separated at intervals by strata of white volcanic lapilli. The depth at which Pompeii is overspread does not exceed 14 feet, and that at Stabiae probably is nearly the same; whilst at Herculaneum the mass of tuff alone above the theatre is not less than 85 feet, over which, it is stated, occur 12 or 14 palms of common soil, and this is covered again by a true lava, probably of much more recent date. That the tufa was at first soft, is evident, from the impression of a woman's breast, and other parts of the figure being found in this volcanic deposit, possessing, it is said, a sharpness, equal to that of a cast in Paris plaster.

The difference between the substance which overwhelmed these cities, is evinced by the state of the papyri discovered in the houses, that have been since freed from the load of matter which had encumbered them. In those met with at Pompeii and Stabiae, which are covered by a more uncemented congeries of sand and stones, decomposition has proceeded so far, that their contents are illegible, and the vegetable matter, it is said, has been replaced, by a grey, pulverulent tuff, probably washed into them by the rains of many centuries.

At Herculaneum, on the contrary, though the manuscripts may have been carbonized, probably by the wet which first penetrated into them from this aqueous inundation, yet any further decay has been prevented by the thick covering of tufa, and the writing is, therefore, in many instances, found to be legible.

No lava appears to have been ejected by this eruption; but it is not improbable that a cone occupying the site of the present one may have been formed by it, and that the mountain thus exchanged the appearance which seems to have belonged to it at the time of Strabo, for one more approaching to that which it exhibits at present.

Of this memorable eruption we have a lively description in the letters of the Younger Pliny, whose uncle, the celebrated Naturalist, fell a victim to his zeal in exploring its phenomena. Yet it is remarkable, that no notice is taken, either by this eye-witness, nor by any writer who lived near the time at which the catastrophe happened, whose Works have come down to us, of the fate of three such considerable towns, although the testimony of Dion Cassius, coupled with that of Martial, serve to identify their destruction with this particular epoch.

The second eruption appears to have happened in the year 203, under the Emperor Severus, and is described by Dion Cassius and Galen; the third in 472, which is said by Procopius to have covered all Europe with ashes, and to have spread alarm even at Constantinople. Other eruptions are recorded in the years 512, 685, and 993. The next, in 1036, is supposed to have been the

first which was attended with an ejection of lava; in preceding accounts we hear only of sand and lapilli being thrown out.

Between that period and the commencement of the XVIIth Century, the mountain appears to have been only five times in a state of action; and in 1611, the interior of the crater, according to the report of Braconi, was covered with shrubs, and every thing indicated the profoundest tranquillity. Yet in 1631 one of the most terrible of its eruptions took place, which covered with lava the greater part of the villages lying at its foot, on the side of the Bay of Naples. Torrents of water also issued from the mountain, and completed the work of devastation. The volcano is likewise said to have been in activity in the years 1660, 1682, 1694, and 1698, from which time till the present its intervals of repose have been of shorter duration, though its throes, perhaps, have diminished in violence; for the longest pause since that time was from 1737 to 1751, and no less than eighteen eruptions are noticed in the course of little more than a century, several of which continued with intermissions for the space of four and five years. That of 1737 gave rise to a stream of lava, which passed through the village of Torre del Greco, and continued its course until arrested by the sea, at which time its solid contents were estimated at 33,587,058 cubic feet. Of the latter eruptions, one of the most formidable seems to be that of 1794, recorded by Breislac, himself an eye-witness of it, in his travels through Campania. The torrent of lava, that proceeded from the volcano, again destroyed the town of Torre del Greco, and advanced into the sea to a distance of no less than 362 feet, with a front of 1127 feet.

The eruption of 1813 has been described by Menard de Groye, and that of 1822 by Monticelli and Scrope. According to this latter Geologist, the whole of the upper part of the mountain was on this last occasion blown into the air, by the violence of the explosive force.

It must be confessed, that these descriptions, however interesting, leave us much in the dark with regard to the real nature of the phenomena; partly from the danger and difficulty of approaching the scene of operations, near enough to examine the products at the time of their ejection, but still more, from a want of due chemical knowledge in the observers themselves, such as should enable them to profit by the facts before them.

On this account, the remarks of Gay Lussac and Sir H. Davy, cursory as they are, exceed in scientific interest the more elaborate descriptions given by others; and if we abstain from noticing them at present, it is only because the results of their inquiries will appear more in place, if introduced hereafter.

#### *Phlegrean Fields.*

It is important, however, to observe, that since Vesuvius has resumed its activity, the numerous volcanic vents which exist on the other side of the Bay, (see pl. vi. fig. 2.) have sunk into a state of comparative inaction; for ancient writers, who are silent respecting the former, speak of the mephitic vapours of the Lake Avernus, as destructive to animal existence; and in earlier days than these, Homer pictures to us the Phlegrean Fields, as the entrance to the Infernal Regions, being placed at the utmost limits of the habitable world, unenlightened either by the rising or the setting sun, with groves consecrated to Proserpine, and enveloped in an eternal gloom



*Solfatara.*

At present the only traces of activity that exist, are observable in the crater called the Solfatara, which occurs immediately above the little town of Puzzuoli. The rock of which this volcano is composed, is a hard and dark coloured trachyte, for the most part porphyritic, and containing more iron than belongs to this rock in general. It has given off a single stream of lava, which descends in the direction of the sea, terminating in an abrupt promontory called the Monte Olibano, and remarkable, as an instance of a true trachytic lava, consisting of little else than felspar, only occasionally intermixed with augite. It has been conjectured that it was the fruit of an eruption in the year 1198, said, though on rather doubtful testimony, to have taken place from the Solfatara.

The crater of this volcano is nearly oval, its greatest diameter being 2337 French feet, its smaller 1800 feet; and the continual evolution of sulphureous vapours, which has gone on from the earlier records to the present time, has naturally produced remarkable changes in the rocks surrounding it. The first stage of alteration seems to be a mere whitening of the mass, in consequence, doubtless, of the removal of the iron, to which its colour is attributable; in the next the rock becomes porous and fissile; when the process is further advanced, it acquires an honey-combed and spongy consistency; and at length it crumbles into a white powder, consisting almost entirely of silex. The rocks surrounding the Solfatara have consequently that white colour, which has given to them, in ancient times, the name of Colles Leucogei; and the saline ingredients, with which those in the crater itself are impregnated, are natural effects of the action of the sulphuretted hydrogen emitted, upon the alkali, the iron, and the alumina, which were its constituent parts. That a mountain so circumstanced should possess numerous internal cavities, is only a natural consequence of the continual penetration of corrosive vapours during the course of so many centuries; so that we may save ourselves the trouble of inquiring, whether the hollow sound, which it emits when struck, might be produced by any other cause, when the porous nature of the ground affords us so simple a solution of it.

*Monte Nuovo.*

The throwing up of a new mountain in the XVIth Century by volcanic agency, took place so much in the vicinity of the Solfatara, that it may seem to belong to its history. After a succession of earthquakes, and, as we are told, the bursting out of flames from the ground, in many places round about the Solfatara, there opened from the sea a gulf, from which, smoke, pumice, lapilli, and sand, were ejected with the noise of thunder. These masses fell in such abundance, that the sand was distributed, not only over Naples, but even to a distance of thirty miles from it, whilst the heavier and more bulky masses accumulated round the orifice to such an extent, that in two, or at most in five days, they constituted a conical hill, now called the Monte Nuovo, 8000 feet in circumference, and 413 in perpendicular height, with an internal crater about a quarter of a mile round, and in depth nearly equal to the elevation of the mountain itself.

The sand near the foot of the mountain, even underneath the sea, possesses so high a temperature, when

brought up from a point, a little below the surface which touches the water, that we are led to believe the volcanic action to be still going on to a certain extent; an inference confirmed by the extreme heat of the water which gushes out from the rock in a cavern not far distant, called the Baths of Nero, which is sufficient to boil an egg, and amounts, according to Mr. Forbes, who has given the most accurate account of it from personal inspection, to 189° of Fahrenheit.

Such are the principal indications of volcanic agency, that have been handed down to us by history, as occurring in the neighbourhood of Naples; but the physical structure of the country is such as leads to a belief, that similar phenomena must have occurred elsewhere, since the country acquired its present general configuration.

*Grotto del Cane.*

The Lake Agnano, from its circular form, and the nature of the materials surrounding it, was evidently the crater of a volcano, which still communicates heat to a spring of water on its borders, and, probably, causes that continual evolution of carbonic acid, which fills the well-known Grotto del Cane. The Lake Avernus seems also to be of similar origin; and although there are no indications of a volcanic nature existing in it at present, yet the term, *gordens Aornos*, applied to it by ancient writers, and the noxious effects of its exhalations upon birds that skimmed over its surface, prove that, at a period not very remote, sulphuretted hydrogen was emitted in large quantities from its spiracles.

The Monte Barbara and Monte Astroni are hills, which, from possessing a central and circular cavity on their summits, as well as from their figure and mineral constitution, are evidently derived from volcanic operations, although neither of them appears to have emitted streams of lava. The crater of the latter mountain is still so perfect, as to form a sort of natural inclosure nearly a mile in diameter, appropriated by the King of Naples, as a preserve for his wild boar and other animals destined for the chase.

Many other craters are alluded to by Geologists, as occurring in the vicinity of Naples, but they do not appear to be sufficiently ascertained; and several so designated are evidently mere hollows, derived from the action of water upon rocks, which, though of a volcanic origin, are of an earlier date, and of a somewhat different formation.

*Puzzolana.*

The whole country, indeed, from the sea to the base of the *Apennines*, appears to have been covered, at a time when it was yet submerged under water, by an immense deposit of *puzzolana* or volcanic tuff. This rock is for the most part of a straw-yellow colour, dull, and harsh to the feel, with an earthy fracture, and a loose degree of consistence. It contains imbedded fragments of pumice, obsidian, trachyte, and many other varieties of compact as well as cellular lava, the softer kinds often rounded, the harder mostly angular. It is separated into beds, by intervening layers of loam; pumice, or ferruginous sand, and, in one instance, according to Von Buch, calc-sinter. Shells are noticed as occurring in it, but they are rare, and bones of ruminating animals have likewise been discovered.

The height of this tuff in many places near Naples is very considerable; the hill of the *Camalduli*, which

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risks to an elevation of 1518 English feet above the sea, consists of this material, and to the West of Naples it forms a sort of wall, so lofty and abrupt, that the former inhabitants of the Country apparently found it easier, availing themselves of the soft and friable nature of the stone, to cut through, than to make a road over it.

Such is the origin of the celebrated Grotto of Paustippo, a kind of tunnel 363 toises, or 2178 feet in length, 50 feet in height, and 18 in breadth, which serves as the common medium of communication between Naples and the towns and villages to the West, said to have been originally formed by the Cimmerians, the earliest inhabitants of the Country, who dwelt chiefly in caves hewn out of the soft tuff, and were, therefore, led by successive steps to attempt more extensive excavations. The Romans appear to have merely enlarged, not to have originated it.

Now, though it need not be supposed, that this mass of tuff was originally deposited to equal depths over the whole surface which it covers, yet no one who examines the manner in which it has continued itself into the valleys, not only on the side of Naples, as near Caserta, but also on the opposite side of the Bay, near Sorrento, and elsewhere at the same time, the extreme variation in its height, and the seemingly capricious manner in which it is distributed, can hesitate to suppose, that much which was originally deposited has been subsequently removed by the action of water; and, inasmuch as the general features of the country do not appear to have materially changed since the earliest periods of history, we are drawn to the alternative either of concluding, that the period, at which this mass was originally formed, goes back to a period beyond comparison more remote than that to which history reaches, in order to give time for causes at present in action to work such great changes, or that it has been effected by some more rapid agents of destruction than those at present at work. Either of these suppositions, it is clear, establishes a line of demarcation between the puzzolana and the volcanic rocks before enumerated, which is also confirmed by the indications we possess, that the latter was formed, whilst the greater part of the low country which it covers was still submerged under water.

But if, as seems obvious, the great mass of puzzolana near Naples has been deposited under water, the height above the level of the Mediterranean, which it not unfrequently attains, indicates the existence of great relative changes in the level of the sea and land, attributable either to a rise of the one, or a sinking of the other. The general consideration of this question belongs to another portion of the Treatise, but there are certain indications of a change of level in this district of so remarkable a nature, that it would be improper wholly to omit mention of them on the present occasion.

#### *Temple of Serapis at Puzzuoli.*

One of these relates to the appearances presented by a Temple near the town of Puzzuoli, supposed to be dedicated to Serapis, which appears to have twice changed its relative position to the sea contiguous, having been at some period subsequent to its erection sunk about twenty feet below its original level, and at some later period raised up again, nearly, though not altogether, to its former height. This inference is deduced from the circumstance, of the pillars which now remain erect, being perforated by pholades, at a height of about twelve feet from their pedestals, as if the sea had at one

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time stood at that elevation, which, it is evident, it could not have done at the time the Temple was built. Standing, as this fact appeared to do, alone, it was natural, that various hypotheses should have been suggested, in order to escape from so startling a conclusion, as that of the local rise and subsidence alternately of the spot of ground on which the Temple stood; but to such it is unnecessary to resort, now that we are assured or reminded of other proofs, showing an elevation of land at no remote period both on the North and South of Puzzuoli, of more than twenty feet, and of many similar subsidences to an equal extent in the same neighbourhood. Professor Forbes has the merit of first setting us right on this question, and his arguments have been extended and confirmed by Professor Lyell, in his recent Work, entitled *Principles of Geology*. It therefore appears, that the effects of recent volcanic action have more than once altered the relative level of the sea and land in this neighbourhood, and we are, therefore, brought more readily to admit the possibility, that an extension of the same force, operating more generally, may have elevated the whole mass of the puzzolana, from the level of the sea, to the height at which it now appears.

#### *Islands of Procida and Ischia.*

To complete this brief sketch of the phenomena in the neighbourhood of Naples, we ought to allude to the Islands of Procida and Ischia, which belong to the same system of volcanos. (See pl. vi. fig. 2.) The former island seems to consist entirely of tuff, separated by beds of cellular lava, which are sometimes horizontal, and at others curved and contorted; but Ischia is somewhat more varied in its composition. It is for the most part composed of a rock which seems to consist of very finely comminuted pumice, reagglutinated so as to form a tuff. From the very fine state of division, however, into which it was reduced at the time when it underwent consolidation, a rock has, often, resulted of so homogeneous a texture, as to be considered a variety of felspathic lava, to which, mineralogically speaking, it bears a considerable resemblance, though we are, upon the whole, disposed to class it with the puzzolana of Naples, and the neighbouring Island of Procida. This formation is seen in every part of the Island, and forms the very summit of Monte Epomeo, which rises to a height of perhaps 2000 feet. In the spot, near the town of Foria, we observe intermixed with it huge blocks of trachyte, sometimes thirty feet in diameter, consisting of a congeries of crystals of glassy felspar, often without any kind of intermedium. In another, however, we observe a conical hill called the Monte Tabor, composed entirely of trachyte, and resting upon a bed of clay containing tertiary shells.

Ischia, however, presents evidence of volcanic operations of a more recent date, than can be assigned to those, which occasioned the former, as above noticed.

Heaps of obsidian and pumice, substances almost unknown at Vesuvius, occur at the village of Castaglione, and have been traced by Spallanzani to a crater in the neighbourhood, called Rotaro. Still further to the East we cross the stream of lava, which issued from the side of the mountain in the year 1302, as we are informed by historians, remarkable for the large crystals of glassy felspar which are imbedded in it. Its surface is still undecomposed, and consequently barren, moss alone growing upon it, and that only in a few parts; a proof of the

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number of ages required for bringing some lavas of a vitreous nature into a state fit for cultivation. This current may be readily traced up the mountain to the point whence it issued, which is marked by the existence of a crater, still named the Capo d'Arso.

Thus Ischia appears to have been subjected to volcanic action of as many different periods as the neighbourhood of Naples itself, its pumiceous conglomerate corresponding with the puzzolana, its trachytes with the rock of the Solfatara, and the lava of the Capo d'Arso with that of Vesuvius.

At present, the only direct indications of volcanic action are seen in the high temperature of the sand on the shore near Monte Vico, which ten feet below the surface is equal to  $110^{\circ}$  of Fahrenheit, and in the hot vapour which issues from the ground in various spots of the same neighbourhood. No eruption of lava has taken place since the XVIIth Century, though occasionally severe earthquakes are felt over the Island, more particularly, it is said, near the ancient point of emission of the Ischian volcano. (Forbes.)

We have dwelt upon the phenomena exhibited by this particular system of volcanos, somewhat more in detail than may be consistent with our general plan, conceiving, that a better notion may be conveyed of the nature of such operations, by particularizing some one district in which they are exemplified, than by any more abstract or generalized description; and certainly no one spot can be selected more illustrative, than the neighbourhood of Naples, as well from the variety of appearances presented, as from the facility with which they can be examined and compared. We must now proceed to specify more briefly the other principal foci of volcanic action, that have at one time or other existed in Italy.

#### Mount Vultur.

On the Eastern side of the Italian Peninsula, in the Province of Basilicata, near Melfi, rises a large isolated hill, called Mount Vultur, which at one time appears to have been a volcano of equal magnitude with that of Vesuvius on the opposite coast.

It is of a conical form, from twenty to thirty miles in diameter at its base, and with two craters on its summit. It is studded over with sundry parasitical cones, and has given rise to several considerable streams of lava.

The nature of the rocks, and the gaseous exhalations that abound in its neighbourhood, bespeak the former prevalence of volcanic action throughout this country, and may lead us to regard the district, as bearing a similar relation to the shores of the Adriatic, which the Campi Phlegrei, as they are termed, do to those of the Mediterranean.

Yet of the eruptions of this volcano, all records are lost in the darkness of antiquity, and we may perhaps refer them to that remote period, when, as has been conjectured, the foot of Mount Vultur was washed by the waters of the Adriatic, which now, from an accumulation of alluvial matter, has receded full thirty miles from it.

Assuming then the space comprehended between latitude  $40^{\circ}$  and  $41^{\circ}$ , as that portion of the Italian Peninsula in which volcanic operations are most rife, we will, in the first place, trace the same appearances Northwards, and afterwards Southwards of this central point.

#### Rocca Monfina.

First, then, near Mola di Gaeta, on the road between Naples and Rome, we recognise on the main land, North-

East of the town of Sessa, extensive traces of volcanic operations, a considerable mountain, called Rocca Monfina, composed of lava and scorice, and retaining vestiges of a crater, appearing to have overspread the whole adjoining district with volcanic materials. Some of these appear to have been ejected since the country was inhabited by man; for the remains of an ancient city have been discovered in digging underneath the town of Sessa, of which, however, as well as of the eruption that destroyed it, no record exists.

#### Ponza Islands.

A few miles out at sea, to the Westward of Mola di Gaeta, lie the Ponza Islands, four of which appear to be entirely volcanic, consisting of trachyte, but are destitute of any crater, and without any stream of lava proceeding from them. They seem, therefore, rather to have been suddenly elevated from the bottom of the sea, than to have been formed by successive ejections of volcanic matter.

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A low tract called the Pontine Marshes, divides these volcanos from the series of rocks near Albano, which in their structure and figure appear to have the same origin.

Near Albano are no less than four lakes, which seem to have been formerly craters.

The immediate vicinity of Rome, commonly denominated the Campagna, is composed of materials, which, though of a volcanic nature, appear to have been heaped together under water.

They consist of loose masses of lava or scorice, feebly agglutinated by fine volcanic sand, and alternating with arenaceous or calcareous beds, containing fresh-water shells, which seem therefore to have been deposited at the bottom of a lake. Hence although certain obscure notices of volcanic phenomena that occur in the history of ancient Rome, may lead us to infer, that the forces had not altogether spent themselves at the time the country began to be inhabited, yet it seems probable, that the eruptions occurred principally at a more remote period, when the Campagna was covered with water, and the higher parts of the country alone constituted dry land.

Evident traces of volcanic operations of an early period occur near Viterbo, and extend Northwards to Radicofani, but we have no records of their date, and but imperfect accounts of their effects.

#### North of Italy.

Indications of the same nature exist probably further North in the neighbourhood of Volterra, where occur pools of water called Lagunes, rendered boiling by the passage through them of sulphuretted hydrogen, which carries with it a little boracic acid.

But less equivocal proofs of volcanic agency are found near the foot of the Apennines in the neighbourhood of Verona, Vicenza, and Padua.

Extensive beds of volcanic tuff there occur, alternating with deposits charged with shells belonging to the newer tertiary period, with which is connected a group of trachytic rocks, constituting the Euganean Hills, which have burst through chalk. Every thing concurs to prove, that the whole or the greater part of these rocks were formed during the tertiary period, and consequently that they belong to the more ancient or antediluvian class of volcanos.

Having enumerated the principal foci of volcanic action North of Naples, we must retrace our steps, and

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examine what indications of the kind are to be discovered to the South.

In Calabria, harassed as it has been by earthquakes, no genuine traces of volcanic agency have been discovered, but in the sea to the West of it occurs the group of the Lipari Islands, which are derived exclusively from this cause.

#### *Lipari Islands.*

These, however, although built up by the action of pre-existing volcanos, appear at present in a great degree exempt from their influence; the only remaining indications of the kind being those presented, by certain hot springs, which in this case we cannot hesitate to refer to such a cause, by a Solfatara in one of the smaller Islands, that of Volcano, and by the volcanic eruptions of Stromboli. The latter differs from most other burning mountains in the uninterrupted character of its eruptions, which have indeed continued, from a period at least antecedent to the Christian Era, at intervals of a few minutes, but without any ejections of lava accompanying them.

The great mass of this, as well as of most of the other Islands, is composed of beds of volcanic tuff or puzzolana, occasionally penetrated by dykes of slaggy lava, which sometimes traverse the contiguous beds in a manner so conformable to the stratification, that, until traced to some extent, they might be mistaken for beds. Then, indeed, they display their true character, either by the disturbance they occasion in the beds which they traverse, or by some deviation from their original direction. (See pl. v. fig. 1 and 2.) The peculiar feature of the volcanic products of the Lipari Islands, however, consists in the abundance of pumice and obsidian, two different states of igneous productions, but rarely, if at all, met with amongst the volcanos of Naples.

In the South of Lipari, the whole surface is covered with pumice, which forms several considerable hills, and extends to the furthest point of the Island.

The obsidian also occurs in extensive beds, or forming a sort of breccia, angular masses of it being held together by a white earthy-looking paste, which is hard and gritty.

#### *Sicily.*

The Island of Sicily contains a great variety of rocks of ancient formation, in which nothing of a volcanic nature can be detected; but, from a period comparatively recent, igneous and aqueous groups seem to have gone hand in hand, in building up the rocks of which its surface is composed.

In the lower extremity of the Island there occur various alternations of volcanic with neptunian deposits, constituting a considerable tract, containing within it hills from one to two thousand feet in height. The volcanic rocks, though sometimes compact, are usually more or less cellular. The cells are occasionally empty, but at other times are filled with various crystalline minerals. The neptunian, according to Professor Lyell, contain marine shells, the greater part of which are identical with existing species, though a few are extinct, belonging to the newer pleocene era. Hence the volcanic eruptions, of which Sicily affords the records, numerous and extensive as they are, do not go back to an era more remote than the newer tertiary deposits. The great *marly* formation, indeed, which occupies a large surface in Sicily, and is characterised by immense deposits of sulphur, marine salt, gypsum, and other sulphuric salts, may probably be connected with certain great submarine eruptions; but we are prevented from

clearly giving the date of this formation, in consequence of the absence from it of organic remains, with the existence of which the exhalations that gave rise to the sulphureous deposits seem to have been incompatible. In this formation occurs a phenomenon, commonly, though we conceive improperly, denominated, an *air volcano*. The most noted instance is at Macaluba near Girgenti; but as we shall consider in another place how far it may be regarded as connected with volcanic agency, we shall at present omit any more particular mention of it. It may serve to convey some kind of idea of the extended period during which volcanic operations have continued in this Country, when we are told, that the whole probably of Mount Etna belongs to a period more recent than the lavas of the Val di Noto. At its foot, indeed, are several isolated rocks; as, for example, the Cyclopean rocks off the coast near Catania, that of La Motte, &c. which seem to belong to the class of submarine lavas, and may perhaps be as ancient as some of those already mentioned; but Etna itself is made up, superficially at least, of a series of beds of lava and tuff, all of which possess the characters of subaerial volcanic products.

Yet according to the joint testimony of Sir John Herschel and Captain Smyth, this mountain has an elevation of about 10,000 feet, with a circumference of 90 miles, whilst, from the descriptions given by Professor Lyell of those valleys, which display the internal constitution of the mountain, and particularly that of the Val del Bove, the whole of that portion of it, which is exposed to view, appears to consist of a succession of lava beds and of tuff, intersected by dykes of trachyte and basalt. (See pl. iv. fig. 4.)

How vast then must have been the period employed in the heaping up of so enormous a mass of volcanic products, unless, indeed, the scantiness of time was compensated by increased energy of action, and the earlier portions of the history of this volcano were marked by more frequent eruptions than the later ones.

Yet, to conclude, that during the whole of this period no deluge could have washed over the country, seems an hasty assumption, implying a more thorough acquaintance with the force of the diluvial currents, and the extent of their operation upon the strata, than we can lay claim to, and likewise overlooking the manner, in which the effects produced upon the surface of this particular mountain may afterwards have been disguised by the eruptions that succeeded. We shall therefore content ourselves with that more general statement, which seems warranted by the facts before us, namely, that all the eruptions of Mount Etna, of which we have any cognizance, took place in the air, and that consequently the earliest of them do not in all probability date from so early a period, as those of the Val di Noto, which occurred, in part, at least, under water, and are covered with neptunian deposits of the tertiary period.

#### *Island of Sciaccia.*

The neighbourhood of Sicily has likewise presented us with an example of one of those events, that occur, comparatively speaking, so rarely during the limits of human experience, namely, the breaking out of a volcano apparently on a new site.

On the 18th of July, 1831, a British vessel perceived in the Mediterranean, betwixt the town of Sciaccia in Sicily and the Island of Pantellaria, a high irregular column of white smoke or steam, which, upon coming

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near, proved to be caused by a small hillock of a dark colour, elevated a few feet above the sea, which appeared to be constantly discharging stones and dust together with vast volumes of steam.

The volcano went on increasing in bulk, till it had attained by the middle of August a circumference of 3240 feet, and a height of 107. It had a crater of 780 feet in circumference, and it consisted entirely of dark vesicular lava, with a few fragments of calcareous and other rocks, not of a volcanic nature, interspersed.

During the storms of the succeeding Winter, the loose materials of that portion of the Island, which had been elevated above the water, were gradually washed away, and no other monument of it now remains, except a dangerous shoal, with a circular patch of rock in its centre, about forty-two yards in diameter, on which there are for the most part two fathoms of water, but in one spot only nine feet.

It appears from the examinations of Hoffman, that the volcano in question lies in a line, which has been subjected to volcanic action from remote antiquity, ranging from the extinct volcanic Island of Pantellaria, by the sulphureous springs of Sciacca, to Mount Etna.

It is likewise important to remark, that, according to the observations of Captain Smyth, this volcano must have been elevated in very deep water, and that even now, in its immediate vicinity, the soundings indicate successively, ten, twenty, thirty, and forty fathoms.

Till within twenty yards, says Captain Swinburne. I got no bottom, and then eighteen fathoms water, whilst from another account it appears, that at a little distance the soundings were 100 fathoms. Lieutenant Lamert, of the French brig *Armide*, describes a bank extending to the North-East for a mile, which, he says, did not exist before the rising of the volcanic hill, and hence he infers, that, previously to the accumulation of the scoriae by which its existence was manifested, the volcanic force had heaved up a portion of the bed of the Mediterranean. How far such a supposition is consistent with analogy, will be considered hereafter.

#### *Grecian Archipelago.*

If from Italy we turn to the Grecian Archipelago, the phenomena just described will be found to have been repeated, more than once, within the limits of authentic History, near the volcanic Island of Santorino.

Santorino itself (see plate vi. fig. 6) is of a semilunar form, and the horns of its crescent are nearly united, through the medium of two smaller volcanic Islands, called *Thera* and *Aspronisi*, so that they together nearly encircle an area of above six miles in diameter, throughout a great part of which the sea is unfathomable. The beds on all these Islands dip at a slight angle towards the exterior of the group, just as would happen, if these Islands had constituted the walls of one vast crater, formed by the heaving up of the beds from the bottom of the sea, as Von Buch and Humboldt imagine to have been really the case.

Whether this be the true explanation, or not, of the position of the beds in the three principal Islands, will be considered afterwards; but a similar operation to the one supposed, although on a scale of inferior magnitude, appears to have taken place in more modern times, in the midst of the bay enclosed between the above-mentioned rocks.

Thus, 197 years before Christ, the island of Hiera, now called *Palaia Kammeni*, (plate vi. fig. 6,) is stated

to have been thrown up from the bottom of the sea, and in the reign of Claudius, A. D. 46, another made its appearance, which in the year 726 was joined on to Hiera. In 1573, that called *Little Kammeni* was produced; and lastly, in 1707, *New Kammeni* was raised in the midst of the basin. The latter is distinctly said by the Jesuit Goree to have been heaved up from the bottom, as indeed the other Islands are reported to have been, and he alleges in proof of it, that a large quantity of fresh oysters were found adhering to the rock so thrown up.

Santorino, with its contiguous Islands, is chiefly composed of trachytic conglomerates, and tuffs covered with pumice, though in one part clay slate, and in another, according to Tournesfort, granular limestone, appear.

From Santorino, a line of volcanic operations extends itself through Milo and Argentièrè to the Eastern coast of the Peloponnesus, (see plate vi. fig. 5,) where before Modon (Methone in Argolis) are several rocks, called the Islands of Pelops, of a volcanic nature, and where also a promontory exists of a conical form, which appears at an early period of Greek History to have been heaved up. Ovid alludes to it in his *Metamorphoses*, and Strabo confirms, what otherwise might have been regarded as the fiction of a Poet, stating, that even in his time manifestations of volcanic agency still were observed.

#### *Iceland.*

To complete our account of those decided evidences of volcanic action, which are to be met with in Europe, we must refer to the Island of Iceland, where, from the earliest authentic records till the present day, volcanic operations have continued, on an extraordinary scale, and with intervals rarely exceeding twenty or thirty years between each. The volcanos in that Country are placed in general linearly, and the following ones are enumerated.

Hecla, the last eruption of which was in 1766.

Katlagiaa, which, after an interval of sixty-four years, had a violent eruption in 1823.

Eyafialla Jokul, which, after intermitting for a century, had an eruption in 1821.

Grimvatn, a lake which became the site of an eruption in 1716.

Skaptaa Jokul and Skaptaa Syssel, two contiguous volcanos, experienced violent eruptions in 1783, which ravaged a vast extent of the country adjoining them.

The lava made for itself a passage into the plain at the base of the mountain, by three streams about eight miles apart one from the other. These currents of lava, reuniting, covered a space of more than 1200 square miles. The ejections of ashes which terminated this eruption continued an entire year, during which the whole atmosphere was constantly darkened by thick clouds of cinders.

Other volcanic phenomena are frequent in Iceland. In 1783, a year memorable in its annals for the violence of the eruptions that took place in it, a new Island was thrown up, consisting of high cliffs, a mile in circumference, which, however, the following day, sunk again, leaving nothing but a reef of rocks, from five to thirty fathoms under water, to indicate its former site.

#### *Geysers.*

Although we have abstained in general from noticing the hot springs that occur in volcanic districts, not only as leading us too far, but likewise as tending to introduce amongst the fundamental facts upon which we

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build a set of phenomena, the origin of which some may regard as problematical, yet are we induced by the obvious nature of the connection that subsists between the Geysers or hot springs of Iceland and its volcanoes, as well as by the general interest which attaches to the former, to notice them amongst the effects of the same agency there exerted.

The Geysers are intermittent hot springs, which throw out at intervals a column of water, succeeded by copious volumes of steam.

The intermittent character of the phenomena may be seen explained on very simple principles by Sir George Mackenzie in his *Travels in Iceland*; and there is no doubt, but that the existence of subterranean cavities, serving as recipients for water in a heated bed of rock, and communicating with the surface by narrow orifices, would cause a generation of vapour, which occupying the upper portions of such caverns, would at intervals acquire elasticity enough to expel the water, and thus provide for itself the means of escape.

The water is strongly impregnated with silex, an ingredient almost universally present in hot springs, but in none so abundantly as in these; nor is it improbable, that the high-pressure steam which we know to be generated in this instance, may materially assist in reducing the silica to a state of solution, for it has been found, that even glass becomes quickly corroded by steam of this description, although it resists it when of ordinary elasticity.

The only other active volcano in the North of Europe is that in the Island of Jan Mayen, off the coast of Greenland. This, when visited by the P. Mr. Scoresby in the year 1817, exhibited: the effects of a recent eruption, was found to consist of a black lava, of buff, and of scoriae.

On the summit was a crater, no less than 500 feet in depth, and about 2000 in diameter.

#### *Extinct Volcanoes of Europe.*

Having now enumerated the several sites of volcanic operations in Europe, which still continue in some part or other to exhibit marks of activity, we must next take a rapid survey of those in which the same forces have at some former period incontestably been at work, but where they seem, so far as human experience goes, to have expended themselves.

In this review we shall omit all, excepting those extinct volcanoes which have operated apparently under similar circumstances to those of the present day, passing over altogether the consideration of such rocks, as, though inferred to be volcanic, differ nevertheless from the products of existing ones, in a manner which seems only explicable, by supposing an alteration in the circumstances under which they were ejected.

#### *Portugal.*

In this review, it may be convenient to begin with the most Southern portion of Europe, namely, the Spanish Peninsula, tracing up the indications of the same kind that occur until we reach Germany, above which, it may be observed, no phenomena of the kind are observable; for although in various parts of Great Britain and Ireland, in the Hebrides, the Faroe Islands, and even in the Scandinavian Peninsula, trap rocks of various kinds are extensively developed, yet these, for reasons already assigned, do not come under our present consideration, being nowhere distinctly proved to be produced, as the others have been, in the open air.

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On the Eastern side of the peninsula, we meet with volcanic appearances, in the Province of Algarve, near Cape St. Vincent; and, on the road from Cintra to Maffra, near Lisbon, occur alternations of semivitreous basalt with tertiary limestone. The occurrence here of the former is worth noticing, from the formidable earthquakes with which Lisbon has more than once been visited.

Dolomieu notices also in the Province of Biera, certain volcanic appearances throughout the chain of mountains called Sierra de l'Estrella, but we are not aware, that they have been examined by any more recent observer.

#### *Spain.*

On the Eastern side of the Peninsula occur indications of volcanic action at Cape de Gaieta, near Almeida, and further North, as it is said, in the mountains above Alicante, where earthquakes are frequent and severe; but the most decided and the best established indications of the kind occur in Catalonia, near the town of Olot. No sooner have we descended the Northern declivity of the Pyrenees towards the Eastern extremity of that chain, than we meet with a volcanic district of about fifteen geographical miles from North to South; and about six from West to East, the vents of the eruption ranging linearly in the former direction, whilst the currents of lava have descended in the latter.

There are about fourteen distinct cones with craters, most of them as entire, as those in the neighbourhood of Naples, or on the flanks of Etna. They have broken through sandstone, shale, and limestone, belonging to the tertiary period, but appear to be posterior to the most modern tertiary strata that exist in the neighbourhood, being covered only by the detritus of their own and the contiguous rocks. In the XVth Century the whole of the town of Olot, with the exception of a single house, was thrown down by an earthquake, accompanied, as it is said, by an eruption; but this latter circumstance is regarded by Professor Lyell as apocryphal; and there appears to be no certain record, as to any of the volcanoes of this district having been in an active state during the historical period.

#### *France.*

Traces of volcanic action are found immediately North-East of the Pyrenees, in a little hill, composed of scoræ, and possessing a regular crater, which borders on the sea near the town of Agde, between Beziers and Montpellier. Thence, a line of volcanic rocks, of various degrees of antiquity, extends into the Cevennes, and connects itself with a more extensive igneous formation in the Vivarais. (Dep. d'Ardeche.) The latter extends itself into the contiguous Department of the Haute Loire, where round the town of Puy it is most fully developed; and the same appearances are renewed in the Cantal, near St. Flour, whence they occupy a wide extent of country, until, after forming the elevated range of Mont Dor and the mountains about Clermont, they terminate Northwards near the town of Riom.

To give any thing like a particular account of the rocks comprising these extensive districts, would occupy too much space, but it may be well to state briefly the general characters, that distinguish in all of them the volcanic formations into two great classes.

There is then, in Auvergne, in the Vivarais, and even in the vicinity of Puy en Velay, an extensive group of volcanic hills, possessing craters, and having streams of lava proceeding from them, which in no respect differ,



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Geologically speaking, from the products of igneous action which we witness daily forming before our eyes. Though no records remain of the period in which these lava streams were ejected, still it is evident, from their shaping their course in conformity to the valleys of the district, that no great changes in the external configuration of the country can have taken place, since the period of their ejection; so that this one circumstance constitutes a broad line of distinction between these and other rocks in the same district, which have themselves been acted upon by the causes, that have excavated valleys in the contiguous formations.

It may, indeed, be true, that some of these volcanic rocks are themselves excavated to a considerable extent by the rivers which flow over their surface, as is remarkably exemplified in the Vivarais, where certain lava streams, which manifestly flowed, since the great features of the country had become as they are found at present, have nevertheless been themselves scooped out, to the depth of 70 or even 100 feet, by the action of the streams that flow at their foot.

Practically speaking, however, no one can confound the ravines, which have been channelled in lava streams of more modern date, with the valleys, by which the rivers which excavated these ravines have their course determined; so that the distinction adverted to may be admitted on the score of convenience, even by those who object to the principle on which it is founded. Whether, indeed, the valleys in question have been produced by the continued operation of the same streams, to which we refer the ravines, is a question more fitted for another part of this Treatise; but, as the majority of English Geologists, in speaking of valleys of this description, and of the detritus resulting from their excavation, still retain terms, which appear to recognise the principle of their having been produced in a different manner, designating them, as diluvial valleys, diluvial deposits, &c., so we shall adopt a similar nomenclature with reference to the volcanic products of Auvergne, speaking of those which are posterior to the valleys of the district, as postdiluvial, and those which are themselves hollowed out by valleys of the same character with the contiguous rocks, as antediluvial formations.

The postdiluvial volcanic products, then, are distinguished by the same characters, which belong to the modern lavas of Etna or Vesuvius, and may be traced to craters often preserving nearly unimpaired their original integrity. In Auvergne alone little less than seventy of them have been enumerated, which possess, in general, a great uniformity of character, and evidently all belong to an epoch, at which the adjoining country had already become dry land. In the neighbourhood of Clermont, however, are five conical hills, (see pl. iv. fig. 5.) in the midst of a group of these volcanos, possessing a striking difference in their aspect and constitution. They are composed of an earthy and pulverulent variety of trachyte, called domite, are altogether destitute of craters, but in general lie detached, in the midst of a sort of amphitheatre of volcanic hills, consisting of scoriform pyroxenic lavas.

The loftiest of these mountains, the Puy de Dome, gives its name to the Department in which it is situated; the others, the Puy de Sarcouy, the Grand and Petit Clersou, and the Puy de Chopine, lie contiguous, but are so detached one from the other, that it would seem impossible to imagine them parts of a formation that once spread over the intervening country, even if there

were not other difficulties in the way of such a supposition. It was the appearances of these rocks, that originally suggested to Von Buch, in an early stage of his career, the theory, which he has since applied to other volcanic formations in different parts of the World, with regard to the heaving up of conical masses of rock, previously softened, by the force of the elastic vapours generated by volcanic operations. The phenomena presented by one of these hills, the Puy Chopine, strongly confirm this view; as we see there an intermixture of trachyte, with granite, and other primitive rocks in various states of alteration, according, as it should seem, to the different degrees, in which they have been severally affected by the igneous action, to which their elevation is attributable. The Puy itself is situated in a sort of crater, the walls of which are composed of scoriform lavas of the ordinary description. The five domitic hills just alluded to, may, perhaps, belong to the postdiluvial class of volcanos, but at a short distance from them occurs an elevated and extensive table land, called the Mont Dor, the great mass of which consists of trachyte, of a more compact and crystalline description, and clearly of an older date. Vast masses of tuff, similar to the puzzolana near Naples, accompany it, and the whole is capped, either with basalt, as is the case at Mont Dor, or by porphyry slate, as in the neighbouring Department of Cantal, where this same formation extends itself. The whole rests upon the freshwater limestone belonging to the tertiary period, which, however, in a few places, alternates with it, and it is intersected by valleys as wide and as profound, as those which traverse any of the older rocks in the contiguous country. These, therefore, we shall venture to denominate antediluvial, in order to mark the difference, both in character and in age, that exists between them and the rocks before mentioned. These last, indeed, appear from various circumstances to have been formed under water, and can, in no instance, be traced to any crater or focus of eruption; whether it was, that the changes that have subsequently taken place in the country obliterated the traces of them, or, what is more probable, that they were originally ejected through the medium of dykes, and under a pressure which confined the focus of eruption within the narrowest limits.

Be that as it may, it is certain, that the appearances presented by the volcanic rocks of Mont Dor and Cantal are of a totally distinct character from those of Vesuvius or Etna. Instead of narrow bands of lava covered with beds of tuff or loose scorice, these mountains present continuous beds of trachyte, basalt, and conglomerate, mantling round the axis of the chain, and interrupted only by the valleys which intersect them. How these rocks could have been brought into their present inclined position, will be a matter for subsequent inquiry; at present, we are only concerned with the circumstances, in which the structure of these mountains differs from that of the volcanos now forming under our eyes.

The structure of the volcanic district in the Velay and Vivarais is of an analogous kind, consisting of immensely thick deposits of volcanic tuff, generally resting on a fresh-water tertiary limestone, and of rocks of trachyte and porphyry slate, which appear to be of subsequent date, and to have forced themselves through the tuff which they overhang.

The depth of the valleys, excavated in this great tufaceous deposit near the Puy, serves to evince, either the long continuance, or the energetic action of the causes

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which have since affected it, and the irregularly abrupt and almost pyramidal form, which belongs to some of the detached hillocks, which lie scattered over the valley, as that on which the cathedral and part of the town of Puy is built, and as the contiguous rock of St. Michael, evinces the irregular manner in which this material decomposes, and the firmness with which its parts in certain positions cohere. The last-mentioned districts also, like those of Auvergne, display many indications of volcanos possessing a more recent date, such as craters still remaining in all their original integrity, beds of scorice which have been ejected, as at present, in the open air, and lava streams, which have descended into the valleys in conformity with the present configuration of the country. Some of these lava streams, however, are themselves deeply channelled by the rivulets that flow across them, and being composed of compact and columnar trap, the sides of the ravine are flanked by basaltic colonnades.

#### Germany.

In proceeding to Germany, we may remark, that a chain of primary rocks, with many secondary formations superposed, stretches with certain interruptions through the heart of the country from East to West, of which the several portions are respectively distinguished by the names of the Thuringerwald, the Fichtelgebirge, the Erzgebirge, the Riesengebirge, &c. In connection with this great back-bone, as we may term it, of Germany, and on either side of it, occur groups of volcanic cones, or other indications of an igneous character, whilst to the North of the above line they are entirely wanting.

#### Eifel Volcanos.

Beginning with the Rhenish Provinces, we observe immediately at the foot of the Ardennes, in a district called the Eifel, a cluster of little volcanic cones, composed, for the most part, of loose scorice, and frequently having very perfect craters, which sometimes serve as reservoirs for the waters of the country, and thus are converted into lakes; at other times are dry, and exist in all their original integrity. Accordingly, notwithstanding the silence of history concerning their eruptions, we can scarcely dispossess ourselves of the idea that they were the work of a recent period, and are persuaded, that they at least belong to as late a Geological epoch as that which we have assigned to some of the volcanos of Sicily and Naples.

They are remarkable for the general absence of any lava-currents proceeding from them, being for the most part mere aggregates of scorice, or a sort of volcanic tuff, made up of pulverulent materials ranged round a central aperture. They in some cases consist merely of the ordinary rocks, upheaved, but in other respects but little altered in appearance. The above, however, appear to be the only vestiges of volcanic action in Germany, that admit of being clearly referred to the same modern epoch, the other rocks, which bear marks of a similar origin, being destitute of craters, and more compact in their structure.

#### Siebengebirge.

On the Eastern bank of the Rhine, opposite to Bonn, rises abruptly from the borders of the river the chain of mountains, called the Siebengebirge, from the seven principal peaks that strike the eye from a distance.

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They are composed, partly of basalt, and partly of trachyte, which appear to have been protruded through the schists, that constitute the fundamental rocks of the district. The superposition of the volcanic products to the brown coal so extensively met with in this Province, is, however, decisive with regard to the tertiary origin of this deposit. The Siebengebirge are, in fact, a prolongation of the extensive basaltic formation of the Westerwald, which again is connected with another considerable volcanic district North-East of Frankfurt, called the Vogelsgebirge.

From the latter, the isolated basaltic cones, of Frankfurt and Hanau on the one side, and of Cassel and Eisenach on the other, seem to be ramifications. In many of these basaltic rocks, the compactness of structure is quite equal to that of the trap in older formations, but in other cases, they are associated with vesicular lavas, which occur less frequently at least, if they are not entirely absent, in the latter. The contact between the volcanic material, and the contiguous stratum, has often been productive of very striking changes in the structure of the rock, rendering, in particular, the sandstone hard and prismatic, just in the same manner as is done in some parts of this country by artificial heat.

Higher up the Rhine, occur several groups of rocks possessing a similar origin to the above. In the Odenwald, near Heidelberg, rise some eminences from the midst of the new red sandstone, in which basalt is found associated with augite rock; and near Freyburg, in the Brisgau, is the series of hills, of which that called the Kaiserstuhl is the most prominent, destitute of craters, but containing, intermixed or associated with compact rocks, vesicular products much resembling recent lavas. Lastly, a few miles to the North of the Lake of Constance, is the commencement of another chain of basaltic and porphyritic cones, connected with which, are certain overlying masses of basalt in Wirtemberg, along the chain of the Rauhe Alp South of Tübingen. These latter, however, have more of the characters which mark the older trap rocks.

In the Rhöngebirge, a group of mountains East of Fulda, a continuation of the same volcanic formation has been noticed, though recent observers have pronounced it to be destitute of craters; and at the Fichtelgebirge, on the North-Eastern limit of Bohemia, occurs a series of basaltic cones extending from Egra to Parkstein.

The same rocks may be traced to Toeplitz in Bohemia, and to the Riesengebirge in Silesia, whilst on the lower side of this chain of mountains, which is there called the Erzgebirge, occur several platforms, cones, and domes of basalt, overlying the other rocks of the country, and therefore posterior to them all. It was these, which impressed Werner with the idea of the aqueous origin of trap, from the marked contrast he observed between the characters and position belonging to these rocks, and to the volcanic products of the present day.

Lastly, on the Western border of Moravia, near the frontier of Hungary, is a small basaltic deposit near Banow.

The above statement, it is feared, affords but an imperfect enumeration of the several sites, in which volcanic action has at former periods of the Earth's history manifested itself throughout Germany, whilst it is probable, that many of the trap rocks alluded to belong to the class, which has been in general omitted, namely, that of submarine lavas; nevertheless it may have its use, in point-



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ing out an important fact in the natural history of volcanos, namely, the *linear* direction which they assume, and their connection with the leading chains of mountains in the country, corresponding also with the direction, in which the shocks of earthquakes are most commonly propagated, and in which hot springs occur.

#### Hungary.

Connected with some of the more Eastern of these groups, is a very extensive volcanic formation in the North of Hungary, consisting of five principal groups, the first of which, in the district of Sehemnitz and Kremnitz, occupies an elliptical space of about twenty leagues by fifteen.

The second, a smaller group South of the preceding, forming the mountains of Dregeley, near Gran, on the Danube.

The third, a mountain group known by the name of Matra, situated in the heart of Hungary, East of the former.

The fourth, a chain which commences at Tokai, and extends North to the heights of Eperies, in length twenty-eight or thirty leagues, and in breadth about five or six.

The fifth is that of Vihorlet, East of the foregoing group, which is connected with the trachytic mountains of Marmarosch on the borders of Transylvania.

The latter form a wide range extending from Vasarhely near the Western declivity of the Carpathians along the line of the river Marosch, nearly to Cronstadt on the frontiers of Walachia.

Now it is remarkable, that throughout the whole of this tract, studded as it is with indications of volcanic agency, no evidences of a continuance of the same has been discovered, unless the Solfatara of Budoshegy in Transylvania be regarded in that light. Neither do any craters exist, except at the Southern extremity of this latter chain, and perhaps near the Lake of Balaton in Hungary.

In other situations, the prevailing rock is trachyte, which occurs in a state of greater development, and consequently under a greater variety of aspects, than any where else in Europe. This is associated with pumice and other cellular products, which indicate that it was not formed under deep water; an inference confirmed by observing, in the pumiceous conglomerates derived from the trachyte itself, shells of the same age as those met with in the basin of Paris. (Beudant.) It would seem then, that the volcanic eruptions of Hungary took place at a period, when the low country was overspread with extensive fresh-water lakes, of which that of Balaton, near which locality they appear to have continued longer than elsewhere, is the only considerable remnant.

In Styria also, a little to the South-east of Gratz, occurs a series of volcanic hills, grouped round a central trachytic eminence, the Gleichenburg. (See pl. v. fig. 10. for an ideal section of the arrangement of the strata round the central trachyte in that Country.) And it is probable that others exist in many parts of Turkey.

It is certain that on either side of the Sea of Marmora, from the Dardanelles upwards to Constantinople, occur volcanic rocks, whose porous and vitrified aspect announces a modern origin, but they appear to be destitute of craters.

#### On the Volcanos of Asia.

##### Asia Minor.

With the line of extinct volcanos on the shores of the

Bosphorus is probably connected that which has been described by Mr. Webb as existing in the Troad, and which is developed still more extensively in the neighbourhood of Smyrna. The latter district was called, according to Strabo, the Catacecaumene, from its burnt and arid appearance, nor does this ancient Geographer hesitate, to refer the characters it bears, to the action of fire proceeding from the earth. (*απο γήκερου πυρος.*) He also speaks of a Plutonium, or cave exhaling carbonic acid, which still appears to exist in this neighbourhood, a proof of the long continuance of processes resulting from this deep seated cause.

#### Dead Sea.

In Syria, and especially in the neighbourhood of the Dead Sea, occur indications of volcanic action, belonging apparently to a still more recent date; at least, if we are justified in supposing the awful event, relative to the destruction of the cities of the Pentapolis, recorded in the Book of Genesis, of which the Dead Sea is stated as the result, to have been brought about by the immediate operation of volcanic forces.

The exact mode, in which it came to pass, that the River Jordan, which appears at one time to have flowed into the Red Sea, (see pl. vi. fig. 1.) created that expanse of waters which now occupies the valley of the Pentapolis, and in which the stream at present loses itself, must of course continue a matter of surmise, until some adventurous traveller shall have examined the country South of the Dead Sea with Geological eyes. It may, however, be suggested, that if one of those volcanos which, we are told, exist South of the Dead Sea, had given rise to a current of lava of considerable thickness, which took possession of the bed of the river, the waters of so considerable a stream, confined within the compass of the valley, would have spread themselves over it, until they had converted what was before a fertile plain into a wide waste of waters.

Such a supposition is at least agreeable to analogy, for Auvergne alone supplies us with more than one instance of a lake being produced, owing to the ponding up of the waters of a river by a stream of lava: nor ought it to be objected to as inconsistent with the authority of Scripture, which in this, as in other instances, only informs us, with regard to the reality of the event, and the moral end it was intended to answer, without seeking to enlighten us relative to the physical means by which it was brought about.

Dr. Clarke and other travellers notice similar volcanic appearances in Palestine; and some of the sacred Prophets, from certain allusions that occur in their writings, appear to have been eye-witnesses of, or at least familiarly acquainted with, volcanic phenomena.

#### Red Sea.

The existence of extinct volcanos at Sherm in the Peninsula of Mount Sinai, may enable us to connect the phenomena exhibited in Palestine with the active volcano of the Island of Habel Teir in the Red Sea, and with other appearances of the same kind that have been noticed in Arabia.

#### Central Asia.

There is reason also to believe, that volcanic operations may be traced along a line, where we should be least disposed to anticipate their occurrence; namely, across the centre of the great Asiatic Continent. To the West

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and South of the Caspian lies the chain of the Caucasus, which presents in many parts indications of the kind. Mount Ararat itself is stated to be an extinct volcano, and some mountains further North, near the River Kuban, are stated to be composed of materials similar to those of the trachytic hills near Bonn. Demavend, the highest peak in the chain of Elburs, itself a branch of the Caucasus, is an extinct, if it be not now an active, volcano, for it is reputed sometimes to emit smoke, and Morier mentions traces of the action of fire South of this point, between Teheran and Ispahan.

If we cast our eye on the mass of Central Asia, we may observe a series of lakes or seas, of which the Caspian is the most Eastern, extending far into the Chinese territory. These lakes are indications of a great depression of the Earth's surface, which Humboldt conjectures to extend Northward to the Frozen Sea, at the mouth of the River Ob, on the Eastern side of the Oural mountains, and which stretches Eastwards between the two nearly parallel ranges, the Altai and the Teen-shan or Celestial mountains. This depression is not merely a relative, but an absolute one, for Engelhardt and Parrot have ascertained by barometrical measurement (and the same has been confirmed in a very remarkable manner, by the observations made on the boiling point of water by a recent English traveller Captain Monteith) that the Caspian, which occupies its present level, is below the surface of the Ocean; and the existence of salt in the soil as well as in the lakes, together with the presence of sea-shells identical with existing species, indicate, that at no very remote era, Geologically speaking, a large portion at least of this tract was occupied by water, of which the Caspian, the Lakes of Aral, Baikal, &c. are the residue.

Now it is in this depressed portion of the great Asiatic Continent, that the volcanos, which are reputed to exist in Central Tartary, have broken out.

The extinct volcano of Aral Toobe, which is an Island in the Lake of Alakul, and the Solfatara, as Remusat calls it, or the active volcano, as Humboldt is inclined to consider it, of Pecosan or the White Mountain, both lie on the Northern declivity of the Celestial Mountains, the latter not very distant from the Lake of Issikoul, which appears to be about double the size of that of Geneva. It had an eruption in the VIIth Century. In its neighbourhood is a mountain called Ourumski, five leagues in circumference, which produces immense quantities of sal-ammoniac, and which probably is the crater of a Solfatara, or half-extinguished volcano. Near the Lake of Darlai also is a small mountain full of fissures rising out of a plain adjoining the banks of the River Kobok, in which the same salt sublimes.

Eastward of Pechan, the whole Northern slope of the Celestial Mountains presents volcanic phenomena, for lava and pumice abound, and various exhalations are here and there emitted.

Southward of the same chain also occurs the volcano of Tourfan, in latitude  $48^{\circ} 34'$ , called Ho-Tcheou, town of fire; though it seems doubtful, whether this be in an active condition at present. It is said to be in the midst of several considerable, though, according to Humboldt, shallow lakes, and produces large quantities of sal-ammoniac. Thus Humboldt concludes, that we are acquainted with a volcanic territory in the interior of Asia, the surface of which is upwards of 2500 square leagues, and which is distant 300 or 400 leagues from the sea; a remarkable exception certainly to the general fact of the propinquity of volcanos to the Ocean, though one

not more extraordinary, perhaps, than the position of Jorullo in the centre of Mexico, seeing that all these volcanos, in consequence of their mutual connection, may be supposed to communicate with the lakes, that occur in the longitudinal valley in which they are situated, just as the Mexican volcano, by its connection with the other vents which stretch across the American Continent, appears to be with either Ocean.

#### *Kamtschatka.*

The exact condition, however, in which the volcanos of Central Tartary now continue, must, after all, be open to some uncertainty, seeing they have never yet been examined by any European traveller; and the only ones, whose existence on the Continent of Asia can be looked upon as ascertained, are those in the Peninsula of Kamtschatka, where three in a very active condition are enumerated.

Thence we may, to all appearance, trace a chain of volcanic operations along the Aleutian Islands to the Peninsula of Alaska, in North America, where indications of the kind are said to occur.

Among the Aleutian group, Langdorf has described a rock near the Island of Unalashka, 3000 feet in height, consisting of trachyte, which made its appearance at once from the bottom of the sea in the year 1795, an occurrence, which may serve to render more credible the traditions which have reached us, as to the rise of new Islands elsewhere in the sea.

The volcanos of Kamtschatka are connected again with a very extensive range of similarly formed mountains in Japan, through the medium of those of the Kurule Islands, in which no less than nine active vents are enumerated.

#### *Indian Archipelago.*

Other links in the same extended chain of igneous operations may be observed in the Islands of Loo-Choo, probably in that of Formosa, and in others connecting Japan with the Philippine group. (See pl. vi. fig. 4.)

Luçon, the largest of these, contains three active volcanos, one of which, that of Taal, South of Manilla, had an eruption in 1754. The Islands of Fugo and Magin danoo likewise contain each a burning mountain. The line is thence prolonged through Sanguir and the North-east extremity of Celebes, by Ternate and Fidore to the Moluccas. In Sambawa, belonging to this latter group, one of the most formidable eruptions ever known has been recorded by Sir Stamford Raffles, the effects of which were felt over a space of 300 miles, extending itself through the whole of the Molucca Islands, Java, &c.

From Sambawa a great transverse line of volcanic operations may be traced from East to West. On the West it passes through Java, then bending Northwards is prolonged through Sumatra, and terminates in Barren Island, in the Bay of Bengal, about the 12th degree of North latitude. (See pl. iv. fig. 4.) To the East of Sambawa the volcanic range extends itself to Banda and New Guinea, and then expands over the greater part of the Pacific Ocean, which appears to constitute but one great theatre of volcanic operations.

#### *Pacific Ocean.*

The Islands dispersed over this vast expanse may indeed be referred to two classes; those of low elevation, which appear to consist entirely of coral reefs, and those of more considerable height, chiefly consisting of volcanic peaks. But even the former appear to be in the

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great majority of instances based upon submarine volcanos; for it seems to be ascertained, that madrepores will not commence their building operations at a depth greater than about twenty feet below the surface of water; and where the subjacent stratum has been explored, a rock of volcanic nature has in general been detected as its basis. Among the loftier Islands of the Pacific Ocean occur some of the most remarkable volcanos of the Globe, especially that of Kirauea in the Island of Owhyhee, described by Mr. Ellis, which appears to be in a state of incessant activity, and Mouna-roa, an extinct one, the height of which is calculated at 16,020 feet.

Other volcanos are stated to occur in different parts of that extensive tract, as far as New Caledonia and New Hebrides. The separate mass of New Zealand, with which Norfolk Island is connected, may be viewed as the Northern extremity of the bulwark; its Eastern can hardly be fixed at any nearer point than the coast of America, since it appears, that an active volcano at present exists among the Galapagos only 10 degrees West of Quito.

#### *On the Volcanos of Africa.*

Nor are volcanic phenomena limited to those Islands only which lie Eastward of the Indian Archipelago; for we have reason to believe, that a large proportion of those which may be regarded as dependences upon the Continent of Africa, are derived in great measure from the same cause.

How, indeed, the case may stand with regard to the largest of them, Madagascar, our imperfect acquaintance with that extensive tract affords us but few data for determining; though Ebel (Bau der Erde) states the existence there of a volcano, and some specimens that were sent from thence to the Geological Society seem to corroborate his statement.

We know, however, that the smaller Islands in its vicinity, namely, the Mauritius and the Isle of Bourbon, are made up entirely either of volcanic materials, or of the coralline limestone of modern growth. In the centre of both these Islands rises a conical mountain, constituting the most elevated point of each; but in the Mauritius there is no semblance of volcanic action at present, whereas, in the Isle of Bourbon exists one of the most active vents in the World; for since 1785, the year in which a register of its eruptions was commenced, up to 1801, at least two lava streams annually have been thrown out from the sides of the mountain, and of these, eight have reached the shores of the sea. These currents of lava from the lower part of the mountain are followed by ejections from the craters situated on its summit, and amongst the substances thrown out is that filamentous variety of pumice, which so resembles spun glass in appearance and flexibility.

These lavas are of a trachytic character, but the Island itself is principally composed of beds of compact and amygdaloidal basalt, alternating with tuffs, the whole being intersected by basaltic dykes.

Besides this active volcano, an extinct one of larger size, called Les Fournaises, exists in the West of the Island. On the Continent of Africa itself, we have no well-ascertained instance of volcanic agency, though the German traveller Ruppell reports, that in Kurdoan, 150 leagues from the Red Sea, and, consequently, far in the interior, a conical and smoking mountain was stated to him as existing.

We will proceed, therefore, to the Islands on the

Western side of Africa, beginning with St. Helena, which appears to be made up of coralline limestone and volcanic matter, the disposition of the latter being towards the centre of the Island, where a crater-shaped cavity exists.

The Island of Ascension, of Tristan d'Acunha, and that called Gough's Island, are also volcanic, and so likewise are those of Fernando Po and Prince's Island, in the Bight of Biafra.

The Cape Verd Islands are composed chiefly of tertiary limestones and volcanic products, but no active volcano exists amongst them, except in the Island of Fuego, which is reported to be in a state of constant activity.

#### *Canary Islands.*

Ferro, the next in the series, is volcanic, and a burning mountain burst out in it in 1677, which again, in 1692, caused an eruption of six weeks' duration.

Indeed, the whole group of the Canaries seems to be placed within the sphere of the same submarine volcano; for although vestiges of other rocks are met with, as of granite and mica slate in Gomera, and of limestone in Great Canary, Fortaventura, and Lanzarote, yet none of these Islands are exempt from occasional manifestations of the same igneous action.

#### *Teneriffe*

In the Island of Teneriffe we see exemplified, almost every variety of volcanic product that elsewhere exists.

The Peak, a conical mountain which rises to the height of about 12,000 feet, is itself composed of trachyte, but it rises out from the midst of rocks, consisting of basalt and the compacter forms of pyroxenic lavas.

The crater of the Peak has given rise to ejections of vitreous lavas, partaking of the character of obsidian, together with loose masses of this substance and of pumice.

At present, however, the principal eruptions take place from the flanks of the mountain, and at a much lower level, namely, from the parasitic cone of the mountain Chahorra, which bears the same relation to the Peak, that the Monte Rosso does to Etna; and it is remarkable, that pumice never has been thrown out by any of these later paroxysms, the products of which are lavas or loose masses, possessing a stony aspect, a black colour, and a large proportion of pyroxene; substances, in short, bearing the same relation to the compact traps constituting the basis of the mountain, which the trachytes do to the clay porphyries found amongst older rocks.

The remainder of the group, as described by Von Buch, appears to consist of submarine lavas similar to those which constitute the base of Teneriffe; in the Islands of Great Canary, of Palma, and others, the beds composing them rise in all directions upwards towards the centre of the Island, where occurs a circular cavity, called a Caldera, similar in shape to a crater, but destitute of lava currents, more profound and abrupt, and of greater circumference.

The Caldera in the Isle of Palma is 5000 feet in depth, and about two leagues in diameter, and from its summit, the edges of the beds, of which the Island is composed, are seen in regular succession, intersected by a network of basaltic dykes.

Another prominent feature in these Islands, is the occurrence of deep and abrupt valleys called Barancos, which intersect the strata, radiating in all directions

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from the centre to the circumference. Their precipitous escarpments, and the absence of any streams running through them, plainly denote that they owe their origin, not to water, but to something connected with the peculiar physical structure of the Island; and Von Buch observes, that both the position of the rocks themselves and the barancos with which they are intersected, admit of a simple explanation, if we suppose a succession of submarine lava-beds to have been upheaved by the action of elastic vapours from the bottom of the sea, the Caldera, towards which all the strata rise, being the point that first yielded to the force applied, the Barancos, a natural consequence of the splitting, which would be caused by the increase of surface over which the rocks were spread, when raised up from their original horizontal position at the bottom of the sea.

As this mode of explanation has, however, been lately disputed, we shall defer the consideration of it to a later portion of this Treatise, and shall, therefore, only remark that the Caldera of Vandama, in the Island of Great Canary, is composed principally of trachyte, (see Von Buch, p. 261.) and therefore could not have been built up by a number of successive eruptions, as has been the case with some craters. (See pl. iv. fig. 3.)

The Island of Lancerote is somewhat differently formed from the rest, presenting a series of not less than twelve little volcanic cones, three or four hundred feet in height, composed of harsh, porous, sharp lapilli, provided each with a crater, lying exactly in a line, as if they had been thrown up from a large fissure or rent extending across the Island, which had a communication with the interior.

Lancerote has been visited with several formidable eruptions, especially one which continued at intervals from 1730 to 1736, so severe as to drive away the inhabitants entirely; and another in 1824, in which a new volcanic mountain was formed by the stones ejected.

Madeira is composed in great measure of the same materials as the foregoing Islands, but no vestiges of any recent volcanic operations are discoverable; and the same remark applies to Porto Santo, which consists of an alternation of the above rocks with tertiary limestones, and sandstones disposed horizontally.

#### Mount Atlas.

Certain parts of Mount Atlas on the Continent of Africa, opposite to the Islands just alluded to, are said likewise to be volcanic.

The mountain called Black Harnsch consists, according to Humboldt, of basaltic rocks of a grotesque form. Its Western ridge, called the Mountain of Soudan, has been explored by Ritchie, who describes it as formed by masses of basalt, which have burst through tertiary limestone containing fossil fish, as in the Vicentin. It was the Mons Ater of Pliny, and if any reliance is placed on the accounts of volcanic appearances reported to have been seen by Hanno whilst circumnavigating that part of Africa, it is more likely, that he should have referred to these mountains, than to the volcanos of Teneriffe, which were too distant from the coast for him to have touched upon.

#### Azores.

The last group of Islands in any degree connected with this portion of the Globe is that of the Azores, and this also is altogether of a volcanic nature. The Island of St. Michael, the largest of them, contains several

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conical hills of trachyte, some of them with craters, and covered by the pumice and obsidian they had ejected. This trachyte has, however, been protruded through strata of basalt and tuff, which constitute the fundamental rocks.

El Pico, the summit of which is 9000 feet above the sea, consists of a conical mass of trachyte, from which smoke is constantly issuing. In 1812, an eruption took place from the Island of St. George contiguous, which was probably connected with this same volcano, considered the only active one in the whole group.

In 1811 a phenomenon occurred near this group of Islands, similar to that already described as having taken place near Sicily, and in the Grecian Archipelago.

After a succession of earthquakes, experienced more or less sensibly in all the neighbouring parts, a new Island rose in the midst of the sea, of a conical form, and with a crater on its summit, from which flame and smoke continually issued. The Island, when visited soon after its appearance by the crew of the British frigate Sabrina, was about a mile in circumference, and 200 or 300 feet above the level of the Ocean.

Like the Island of Sciaccia, however, it sunk again into the sea, after continuing to be visible above the waters for some weeks.

#### On the Volcanos of America.

##### Antilles.

All the smaller Islands constituting the West-Indian Archipelago, are composed either of coralline limestone of very recent formation, or of volcanic materials.

Those which consist wholly of the former, are of extremely low elevation, whilst the volcanic Islands rise often to a considerable height. The latter group may be divided into those which are entirely volcanic, and those which contain an intermixture of calcareous rocks.

The first of these classes comprises the following.

1. Grenada, in which there is an extinct crater filled with water.
2. St. Vincent, the site of an active volcano called *Le Souffrier*, which had a tremendous eruption in 1812.
3. St. Lucia, which also contains a very active volcano.
4. Dominica, the site of an extinct volcano.
5. Montserrat, of a solfatara.
6. Nevis, of the same.
7. St. Christopher's, of ditto.
8. St. Eustachia, of an extinct volcano.

The second division would comprehend,

1. Martinique, which consists chiefly of felspathic lava, constituting its three peaks, but which has calcareous rocks resting upon these volcanic materials.
2. Guadaloupe, one portion of which consists of coralline limestone, the other of volcanic rocks, containing fourteen craters, one of which is in an active condition, and had an eruption in 1797.
3. Antigua, in which calcareous rocks of recent origin predominate.
4. St. Barthelemi.
5. St. Martin.
6. St. Thomas, of which we possess no precise information.

It may be observed, that all those Islands which exhibit traces of the recent action of fire, are situated in a line on the Western boundary of the range, from North latitude  $12^{\circ}$  to  $18^{\circ}$ , and West longitude  $61^{\circ}$  to  $63^{\circ}$ .

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Whatever indications of the kind occur further to the West, belong to eruptions of an older date.

Thus the volcanic islands of the Antilles seem to be the links, which connect the chain of primary mountains in the Caraccas, with that which runs across the Islands of Porto Rico, St. Domingo, Jamaica, and Cuba, both which lie nearly at right angles to that of the volcanic Islands enumerated. Yet the connection between the two is evinced, from the earthquakes, to which the non-volcanic chains above mentioned are so subject, ceasing, upon the breaking out of an eruption in one of the volcanos of the neighbouring Islands.

On the Continent of North America we meet with no recent volcanos further North than California, where three are stated as being at present in activity, although little is actually known concerning them.

#### Mexico.

In Mexico, traces of volcanic action belonging to every Age are strikingly manifest. Basaltic rocks and other modifications of pyroxenic lavas are met with in abundance, but the most elevated parts are composed of trachyte, which appears to have burst through the primary rocks, constituting conical or pointed mountains of enormous height. There would even seem to be a passage from these into granite, through the medium of a species of porphyry, which, though it partakes of the same ingredients as trachyte, is of a compacter texture, and which seems at the same time to be interstratified with the primitive rocks of the country.

But Mexico also presents a chain of active or half-extinguished volcanos, ranging in a linear direction across the Continent, and consequently at right angles to the primary chain above mentioned, which runs North and South.

In the parallel of the City of Mexico occur no less than five burning mountains, placed so much in the same line, that they appear to be derived from a fissure traversing Mexico from West to East; and it is interesting to remark, that if the same parallel line which connects these volcanos be extended in a Western direction, it would traverse the group in the Pacific called the Isles of Rivillagigedo, which there is reason to believe are also volcanic. See plate vi. fig. 3.

The most Eastern of these, that of Tuxtla, is situated a few miles to the North-West of Vera Cruz. In the same Province, but further to the West, occur the volcano of Orizaba, the height of which is 17,300 feet, and the peak of Popocatepetl 300 feet higher, the loftiest eminence in New Spain; whilst on the West of the City of Mexico are the two remaining ones, Colima and Jorullo. The elevation of the former is about 9000 feet. That of the latter much less considerable. It is remarkable, however, as affording us an instance of the breaking out of a volcano in a new spot; for the origin of this mountain dates no further back than the year 1759, when it was suddenly thrown up, with five smaller conical masses, from the midst of the plain called the Malpays, which also, over an area of three or four square miles, was upheaved with an inclination increasing from the circumference to the centre, the former being only thirty-nine feet above the old level, the latter no less than 524 feet. (See plate iv. fig. 1 and 2.)

Thousands of small cones from six to one hundred feet in height, called by the Indians Hornitos, or Ovens, are scattered over this upraised plain; they consist of

clay intermixed with decomposed basalt, and are continually giving out steam.

Jorullo, at the time Humboldt visited it, was still emitting smoke, and had thrown out from its North side an immense quantity of scoriform and basaltic lavas. The surface of the Malpays was also still hot, and two streams of water, which were swallowed up in the hollow caused by the upheaved strata, reappeared on the other side of the plain, as warm springs.

In this brief account of the curious and instructive phenomena of Jorullo, we have taken for our guide, Humboldt, as the only scientific traveller who has given us an account of it, after an actual inspection of the spot. We are aware, indeed, that doubts have been thrown upon his explanation by certain English Geologists, who are reluctant to admit the fact, of upheavings having taken place amongst volcanic materials; but without entering into this question at present, we may remark, that those who admit the uplifting of a whole Island at once from the bed of the Ocean, (and who, that is conversant with volcanic phenomena, can question that such events have occurred?) need feel no difficulty in admitting the testimony of the Indians, or the opinion of Humboldt, with respect to the fact of a mountain like Jorullo having been uplifted bodily from the interior of the Earth.

The active volcanos above enumerated are connected, one with the other, by several which are extinct; thus between Orizaba and Popocatepetl, lies the Cofre de Perote, and between Popocatepetl and Jorullo, the extinct volcano of Mexico, otherwise called Iztaccihuatl, whilst Colima, as we have seen, lies between Jorullo and the Islands of Rivillagigedo above noticed as volcanic.

In the new Republics of Guatemala and Nicaragua, a line of volcanos occurs lying parallel, instead of transversely, to the chain of the Cordilleras. Between North latitude 10° and 15°, twenty-one active vents are enumerated. South of the Isthmus of Darien, in the Republic of Columbia, no less than thirteen occur.

One of these, the Peak of Tolima, is in the department of Cundinamarca, and the Province of Bogota, forty leagues from the coast, and amongst the central Andes. Seven are in the department of Cauca, which extends along the coast of the Pacific; four of them belong to the group of Popayan, and three to that of Pastos, two Provinces comprehended in that department; whilst further South, in the Province of Pichinca, or Quito, belonging to the department of the Equator, are five active volcanos.

The connection between these last, and the volcanos of the department first mentioned, was evinced in 1797 by the following circumstance.

A dense column of smoke had for some months been observed to issue from the volcano of Pasto in the latter Province, which all at once disappeared; and it was afterwards found, that at this exact time the town of Riohomba, sixty-five leagues further South in the Province of Pichinca, which lay contiguous to the volcano of Tunguragua, was destroyed by a fearful earthquake.

It is remarkable that the whole of this line of volcanos lies Westward of the Andes. To the East of this chain exist, indeed, three small vents near the sources of the River Caqueta, Napo, and Morena; but these, according to Humboldt, probably result from the lateral action of those of Popayan and Pasto, whilst Buenos Ayres, Brazil, Guayana, and Venezuela are altogether destitute of these phenomena.

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*South America.*

On the Western side of the Cordilleras, however, the line of volcanic operations would seem to extend uninterruptedly along the whole coast to Chili; for although in the interval of 30 degrees that occurs between the latter Republic and Quito only one burning mountain exists, that of Arequipa in Peru, yet it seems probable, from the frequent earthquakes that agitate the intermediate tract, that the same processes are going on beneath, although no permanent vent exist for the discharge of elastic vapours.

In Chili, sixteen active volcanos are enumerated, of which two only exist on the coast, the rest being situated in the midst of the range of mountains, which runs in a direction nearly parallel to it, but further inland. Thus we may trace a line of volcanic operations along the greater part at least of the Western coast of South America, the loftiest eminences being of trachyte, which encircles in zones a large portion of the table land, but rarely extends into the valleys, forming conical mountains, which often serve as vents for the aeriform or solid materials elaborated below, but at other times are unaccompanied with lava streams or scoria, and apparently have no vestige of any crater.

The latter appears to be the case with Chimborazo, the highest point of the New World, whilst Cotopaxi, the next in point of elevation, has given birth to frequent and violent eruptions.

## SECTION 2.

*Other Phenomena referable to volcanic action.*

We have now completed our proposed sketch of the distribution of those volcanos, which either are in activity at the present time, or, if dormant, have at least left such evident traces of their former existence, in the rocks which they have ejected, or the lava currents which they have poured forth, that we cannot hesitate in regarding their operations, as being of the same nature, and brought about under the same external circumstances, as those of which we are eye-witnesses.

Wide indeed as may be the interval, in an historical sense, between certain of these, as, for instance, between the latest eruption even of the volcanos of Auvergne, and the earliest recorded one of Vesuvius; yet the whole together constitutes the same Geological epoch, one in which the general features of the country were nearly as at present, the climate not materially different, and the races of animals those which are now existing.

And although the earlier volcanic rocks, found in these Countries, were produced at a period to which these remarks do not apply, one in which large fresh-water, and in some instances salt-water, lakes occupied what is now dry land, when the climate was warmer, and the animals in many cases such as now no longer live in any part of the Globe; yet are these so connected in character and position with the more modern products of volcanos alluded to, that we need not hesitate, either to refer them to the same cause, or to comprehend them in our enumeration.

The case of the trap rocks is somewhat different; for though few at present contend that they are of aqueous origin, all must admit, that if produced by volcanic action, it has been by operations differing in some respects from those at present taking place, either in their own nature, or in the external circumstances which influenced them; so that in laying the foundation for a

series of deductions with respect to the nature and effects of subterranean fire, where it may be best to throw aside every thing of an hypothetical character, and to consider only that which is incontestably volcanic, we should do wrong in taking into the account these igneous productions of an earlier Age.

Nevertheless there are certain other phenomena which must be contemplated, if we wish to estimate the amount of volcanic action in all its different phases.

*Earthquakes.*

The first of these is earthquakes, which may be proved on tolerably secure grounds to have, in all cases, a connection more or less intimate with volcanic agency, and ought therefore to be regarded as one of the modes, in which these forces manifest their existence over the Earth's surface at the present day.

In some instances, indeed, earthquakes have occurred so immediately antecedent upon volcanic eruptions, and are so manifestly derived from the same centre of action, that no better proof could be offered to establish an identity of origin.

In other cases, the evidence, though not quite so direct, is perhaps as cogent as need be required, in order to substantiate the point in question. When, for instance, we observe two volcanic districts, both subject to earthquakes, which are ascertained, by their coincidence in time and other circumstances, to have a connection with the volcanic action there going on, and find that an intermediate country, in which there are no traces of the operation of fire, is agitated by subterranean convulsions, similar in kind, but stronger in degree, than those occurring in the immediate vicinity of the volcanos; have we not reason to conclude, that the same action extends throughout the whole of the above area, and that it is this which produces in the intermediate space the effects alluded to, which are often the more violent from the absence of any natural outlet, whence the elastic vapours set in motion, which immediately suggest themselves to us as the cause of the convulsions experienced, could find a channel of escape?

Now, in proof of the former of these positions, it may be scarcely necessary to do more than to appeal to the case of Etna and Vesuvius, which rarely return to a state of activity after an interval of repose, without some antecedent earthquake, the latter usually ceasing, so soon as the volcano has once established for itself a vent, whereby these elastic vapours can discharge themselves. Such was the case before the celebrated eruption of A. D. 79, in Campana, as well as in that of Etna in 1537, when, says Fazzello, noises were heard and shocks experienced over the most distant parts of Sicily. In such cases, no one would pretend to doubt the connection between the volcano and the earthquake.

The second point seems established, by considering the tremendous earthquakes which ravage so often Campana, and those mentioned by Humboldt as intervening between and in the line of the volcanos, of Columbia, Quito, and Chili. Von Buch has shown, in his paper on Lanzerote, the comparative immunity enjoyed by Teneriffe from those convulsions of Nature, which agitate the neighbouring Islands, destitute of that great chimney or safety-valve afforded it by the Peak of Pejde.

But before we are entitled to appeal to earthquakes, as affording an independent source of evidence with respect to the existence of volcanic action, it will be necessary to show, that no other natural cause is likely to

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have produced such effects, more especially as even those who admit their volcanic origin in the above cases, have, nevertheless, been disposed to assign to them a different origin in others. Such a distinction seems to be hinted at by Werner, who acknowledged two classes of earthquakes: the first connected with a particular volcano, and felt only within a radius of some miles from it, and at a period when the latter was in a state of activity; the latter less manifestly related to any such cause, being spread over a much larger tract of country, and, therefore, as he conceived, situated at a much greater depth.

#### *Their Phenomena.*

This renders it necessary for us to pass in review the phenomena most commonly attendant upon earthquakes, in order to ascertain, how far they appear to countenance the supposition, that other causes, besides those of a volcanic nature, might have contributed to produce them.

It would greatly confirm such an opinion, if it could be shown, that there were any phenomena common in one class of volcanos, which were absent from, or uncommon in, the other; but as no one has attempted to make such a distinction, all that remains to be done is to consider generally the concomitants or sequelæ of earthquakes, with a view of ascertaining, how far they are reconcilable to any other than a volcanic cause.

None of these, indeed, can be considered as universal: thus in some earthquakes the shock consists in an horizontal wavy motion; in others in an upward heaving; and in a third class in a vibration backwards and forwards.

There is usually a sort of subterranean noise attending them, which has been compared to thunder, or the rolling of artillery, but this is not constantly present; and on the other hand the noise has been heard without any concomitant earthquake. A peculiar smell of a sulphureous nature has been occasionally experienced, and other phenomena, such as the bursting out of flames from the earth, the overflowing of wells, the ejection of water from fissures formed at the time, are noted in particular cases.

The following may be enumerated as the meteorological phenomena usually coincident with earthquakes.

Irregularities in the season preceding or following the shocks, sudden gusts of wind interrupted by dead calms, violent rains at period where such phenomena are unusual or unknown in the country; a reddening of the Sun's disk, and a haziness in the air often continued for months; an evolution of electric matter from the ground, together with indications of some extraordinary condition of the atmosphere, evinced both by the inferior animals and by man, the former uttering cries of distress, and evincing extraordinary alarm, the latter experiencing a sensation like sea-sickness or dizziness in the head. These phenomena, however, appear to be equally common during the continuance of volcanic eruptions, as of earthquakes, and indicate in both cases the tendency of any great subterranean movement, proceeding from whatever cause, to disturb the equilibrium of the atmosphere.

The only other hypotheses, by which earthquakes have been accounted for, are, that of Stukeley, who refers them to subterranean discharges of electricity, and that of Buffon, who attributes them to the falling in of caverns existing in the interior of the Globe.

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The arguments that have been from time to time advanced in favour of the electrical theory are vague and inconclusive; they are drawn from some fanciful analogies between the noise and shock accompanying lightning, and those which are experienced during an earthquake; from the extreme rapidity with which the motion is propagated, to which the passage of electricity alone is comparable; from the electrical state of the atmosphere both before and after an earthquake; and from the sulphureous smell sometimes perceived, which is thought to resemble that produced by the electrical spark.

No one, however, has yet attempted to show, that any of the above phenomena are limited to those earthquakes which they are disposed to separate from volcanos, neither do they appear by any means incompatible with this view of their nature and origin.

Electrical phenomena are indeed equally common during the continuance of volcanic eruptions, produced in all probability by the evolution of large quantities of steam and other elastic fluids, the decomposition and subsequent regeneration of water, and other processes which accompany these great operations of Nature.

The late discoveries, indeed, which have been made with regard to the opposite electrical condition of mineral veins and the rocks containing them, may lead us to believe, that much remains to be learned with regard to the agency of this mysterious power in the interior of the Earth; yet we can hardly believe, that in the solid strata of the Globe, consisting, as they do, of conductors, the same accumulation of electricity can ever occur, as that which produces the phenomena of thunder and lightning in the atmosphere.

With regard to the theory of Buffon, it may be sufficient to observe, that the existence of cavities in rocks can only be supposed to arise from two causes; something connected, either with their original formation, as in the case of limestones, or with the convulsions that have subsequently affected them.

Now with regard to the *first*, it is highly improbable, that any great spontaneous sinking of hollows, that have existed for so long a period, should take place in the present day; and with respect to the second, the very existence of such hollows implies the previous exertion of volcanic agency, for we know of no other cause in nature, competent to heave up rocks in the manner necessary to produce such cavities.

Besides, although the sudden falling in of a cavity might produce a shock extending over a considerable area, yet there is no reason, why it should spread in one direction more than in another.

In truth, however, the chief difficulty, which prevented our predecessors from acting in this instance on the sound maxim in philosophy, of not assuming more causes for natural effects than were necessary for explaining the phenomena, has been removed by the progress of modern discovery, which, by increasing our knowledge of volcanos, has convinced us, that whilst their manifest distribution is far more extended than we had once supposed, the probable indications of their former agency are to be met with, in almost every part of the Globe where earthquakes have been experienced.

This, of course, renders it more easy to refer earthquakes in general to some focus or other of volcanic operations; especially if we assume, what in itself is highly probable, that the eruptions of burning mountains are only the extreme manifestations of a cause generally diffused throughout Nature, and that the minor



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indications of the same may therefore be looked for, where these mightier ones are unknown.

It has, indeed, been sometimes alleged, that from the wide extent over which the shock of an earthquake is sometimes diffused, the immediate seat of the action must be at a depth incalculably greater, than that which we are disposed to assign, either to volcanos, or any other natural force; and Dr. Stukeley has undertaken to overthrow the volcanic hypothesis by a sort of *reductio ad absurdum* derived from a calculation of this kind; showing, that as the earthquake which occurred in Asia Minor in A. D. 17 extended over a diameter of 300 miles, it must have proceeded from a point 200 miles beneath the surface. The superficial extent, however, of earthquakes need not create a difficulty in the present day, when we are aware of the vast distances to which sound and other vibratory motions may be propagated along the substance of solid bodies, and are therefore at liberty to consider the minor effects of an earthquake, to be merely the undulations of the principal shock, propagated laterally through the strata of the Earth.

Gay Lussac observes, that the shock produced by the head of a pin at one of the ends of a long beam is distinctly transmitted to the other extremity, and thence infers the vast distances, to which that communicated by elastic vapours, suddenly generated, and struggling for escape, might be expected to extend.

This consideration, whilst it renders us cautious as to inferring the existence of volcanic action in every spot where earthquakes are experienced, will enable us to reconcile their phenomena with the more moderate depth, which we are induced from other reasons to assign to volcanos themselves.

Upon the whole, then, we are disposed to regard earthquakes as exclusively of volcanic origin, and consequently to appeal to them, as indicating, in the parts where they manifest themselves in their greatest intensity, the operation of subterranean fire, regarding the minor shocks as mere undulations of the strata, occasioned by the primary impulse communicated.

#### *Thermal Waters.*

Another class of phenomena, which, like earthquakes, are manifestly connected with volcanos in some instances, but may appear of doubtful origin in others, are hot springs; but we confidently expect, that a brief review of the nature of their contents, of the situations in which they are found, and of other circumstances belonging to them, will lead to the same conclusion, to which we arrived in the former instance.

The solid contents of thermal waters, being obviously derived in most instances from the rocks through which they have percolated, afford little either to confirm or to refute this opinion; but the gases which accompany them are plainly to be traced to the immediate source of the heat, and are given off by the processes to which the latter must be referred.

#### *The Gases given out by them.*

Now if it should appear, that the same aeriform fluids are evolved from hot springs, which appear to be emitted by volcanos, a presumption will arise highly favourable to an identity in their respective origins, which will obtain a greater degree of force, in proportion as the gases are generated less commonly by other natural processes.

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Thus sulphuretted hydrogen is an ordinary accompaniment both of volcanos and of thermal waters; but the argument drawn from its presence is weak, because the same gas often occurs in springs possessing only the medium temperature, as the effect of processes totally unconnected with volcanic operations.

The same remark applies to the carbonic acid so frequently present in springs, in a proportion exceeding that in which it would be imparted to them by the atmosphere.

Its frequent connection with volcanos is unquestionable, for there are scarcely any, that do not evolve it, either alone, or through the medium of the springs contiguous; but as any cause, which was adequate to impart heat to the water, might equally produce an evolution of carbonic acid from calcareous and other rocks which contained this ingredient, the proof in the above instance is not stronger than it would be without it.

But there is a third description of air evolved from springs, the presence of which seems better calculated to establish their connection with volcanos, since, unlike the first, it is disengaged in a state of purity by no other known process going on in the interior of the Globe, and unlike the latter, cannot be accounted for, in many instances at least, by the mere action of heat on any of the constituents of the surrounding rock formations.

The gas alluded to is nitrogen, which was detected by Sir H. Davy in the white vapour given off by Vesuvius after its eruption in 1819, mixed with only half its usual quantity of oxygen, and by his brother Dr. John Davy in one sample of gas which he collected near the new volcanic Island off Sicily. Its existence, however, in volcanos is more fully substantiated by the ammoniacal salts copiously evolved by many of them; and it is given off from springs, which so manifestly derive their temperature from their contiguity to the latter, that we can scarcely help placing this gas amongst the commonest products of volcanos, during the more languid conditions of their action. Thus it has been observed by a recent chemist, proceeding in large quantities from a spring at Castellamare, in the Bay of Naples; by Professor Daubeny, mixed with a predominant portion of carbonic acid, in the hot springs of Mont Dor and Bourbonne in Auvergne, and in those of Chaudesaigues in Cantal; and by M. Longchamp at Vichy: all places, be it observed, so connected with the extinct volcanos of Auvergne, that the heat of the springs must, in these instances at least, be referred to a volcanic source.

Now the gas evolved from the thermal waters of the Alps, however distant they may be from volcanos in action during the present condition of the surface, seems to be generally of the same description; the carbonic acid, which may probably have accompanied it, being in these cases absorbed by the water through which it had to pass.

Thus Professor Daubeny discovered it on the Savoy side of that chain, issuing in large quantities from the spring of St. Gervais; and on the Italian side, from those of Sainte Marguerite at Cormayeur, of St. Didier in the same valley, and of Bonneval in the Tarantaise, half-way between the Bourg St. Maurice and the Col de Bonhomme. In only one of these springs did carbonic acid appear to be present, and in this case it amounted to about 12 per cent. of the whole quantity emitted.

Dr. Ure also mentions his having detected azote issuing in a state of purity from the baths of Louèche in



Switzerland. In this Country, the same gas has long ago been detected in the thermal waters of Bath and Buxton; and more recently it has been found by Professor Daubeny in those of Bakewell and Stoney Middleton in Derbyshire, and that of Taaffe's Well in South Wales.

In other portions of the Globe the same gas has been noticed in the thermal waters there met with. Thus Dr. Davy detected it in a state of absolute purity issuing from certain warm springs near Trincomalee in Ceylon, and Boussingault and Rivero in certain ones occurring in the primitive chain of the Cordilleras in Venezuela. (*Annales de Chimie*, vol. xxiii.) It is remarkable, however, that M. Boussingault has since examined certain hot springs in immediate connection with the volcanos of Equinoctial America, and finds them to give out no azote.

The quantity of this gas emitted in a given time is often very remarkable; but the only attempt to obtain a correct estimate of its amount, with which we are acquainted, is that by Professor Daubeny, with respect to the thermal waters of Bath, detailed in a Memoir read before the Royal Society in December, 1833.

It appears, from an average of twenty-four observations made on different days of September and October in that year, that the quantity of gas emitted per minute from the King's bath alone was 267 cubic inches, or about 222 cubic feet in the twenty-four hours. This consisted of about 97 per cent. of nitrogen, and 3 per cent. of oxygen. There was also found a quantity of carbonic acid, varying from  $4\frac{1}{2}$  to 13 per cent.

The quantity of gas emitted differed a little from day to day, but the variation did not appear to depend upon the state of the barometer or other atmospheric changes.

#### *Thermal Waters.—Their Situation.*

The situation of many hot springs tends also strongly to confirm their relation to earthquakes and other physical convulsions, thus connecting them with the same series of natural phenomena.

Where not placed in the vicinity of active or extinct volcanos, (which is the case with the greater number,) some evidence of violence, some rending or dislocation of the contiguous rocks, may often be perceived. Thus they abound near the base of certain chains of mountains, which, in their highly inclined strata, give evidence of having been heaved upwards, but are comparatively rare in the low country, at a distance from those great centres of elevation, where the nature and position of the rocks indicate no changes, excepting those which may have been brought about, either by the sudden and violent, or the slow and continued, action of water.

If, as in England, thermal waters also occur at a distance from any of the great systems of elevation alluded to, it will generally be found, that the spots themselves exhibit proofs of violent, though more local, convulsions having, at some period or other, taken place in their vicinity.

For instances of this kind, derived from other Countries, we may refer to Professor Daubeny's *Memoir on Thermal Waters*;\* on the present occasion, want of space compels us to confine ourselves, to one or two facts drawn from the Geology of England.

Thus the defile, from which issues the tepid spring of St. Vincent's Rocks, near Clifton, is considered by the best observers as the result of some internal derange-

ment of the strata, brought about by disturbing causes of great antiquity; and in like manner, the similar gorge at Matlock, out of which its tepid springs issue, is associated with a great dislocation of the strata, attributable to their having been tilted upwards at an high angle to the West.\*

The same fault has been traced by Mr. Farey as far as Buxton, and from thence to the villages of North Bradwell and Stoney Middleton, in all which places have been noticed springs, possessing a temperature more or less elevated above the medium point of that climate.

We must not, indeed, expect to meet with the same direct evidence, in the case of every hot spring that comes under our examination. At Bath, we know of no dislocations in the strata posterior to the age of the coal and mountain limestone, and it would, perhaps, be rash to connect these with the cause of the thermal waters there existing. Nevertheless, when we consider, in how very large a proportion of cases some indication of an igneous character may be traced, the absence of proof in the few remaining ones may, perhaps, be fairly referred to the imperfection of our knowledge.

The volcanic nature of thermal waters is likewise confirmed, by the relation which seems to subsist in general between the elevation of their temperature, and the date, which we should be induced from other considerations to assign, to the latest manifestations of volcanic agency in the country.

Thus, those which make the *nearest approach* to the boiling point of water, are uniformly found amongst volcanos now in action; next in the order of temperature are those associated with volcanos, which, though now extinct, appear to have existed at a period, Geologically speaking, recent, that is, at a time when the great features of the country were nearly as at present; whilst the springs, which gush out at the foot, or in the midst, of uplifted chains of mountains, at a distance from those rocks which are generally regarded as volcanic, never possess a temperature so elevated, as the two preceding classes of thermal waters sometimes attain to.

Now, if these latter were really produced by other causes than volcanos, it does not seem intelligible, why they should, in all cases, observe that lower degree of heat, which indicates, either a cause of less intensity, or one whose effects have been moderated by a longer intervening space of time.

Lastly, the other solutions of the heat of springs appear on examination totally inadequate to account for their phenomena. In the case of the Bath waters, indeed, the warmth has been attributed to the decomposition of pyrites, in which the lias clay, from whence it issues, abounds; but to this it may be objected, that the same stratum, though equally charged throughout with this mineral, nowhere else throws out springs possessing more than the medium temperature; and yet, the sulphuretted hydrogen, which the latter so frequently contain, shows a decomposition of pyrites to be going on in several other places. Besides, it is remarkable, that thermal waters, far from being impregnated with those saline ingredients, which would naturally enter into

\* A striking instance of the same kind, taken from the Pyrenees, is exhibited in pl. v. fig. 8. at a place called St. Paul de Fenouilhades, Dep. des Pyrénées Orientales. We there see a thermal spring gush out from a narrow gorge in an elsewhere continuous line of hills, the strata of which lose their horizontality and sink abruptly on both sides towards the fissure.

\* *Edinburgh New Philosophical Journal*, Oct. 1831.

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their constitution, if they were caused by the heat generated in consequence of such chemical processes taking place in the interior of the Earth, are, on the contrary, in the great majority of instances, remarkably free from foreign matter. Thus the Bath waters contain not a particle of the sulphuretted hydrogen, or sulphate of iron, which would have arisen from the decomposition of pyrites; and the mineral contents of those connected with primitive chains, such as the Alps or Pyrenees, although obviously referable to the action of water, assisted by heat and pressure, upon felspathic rocks, are far from suggesting any distinct chemical operation, by which this heat could have been elicited.

Upon the whole, without pretending, that the evidence in the case of thermal waters is so conclusive as in that of earthquakes, or denying, that there may be instances, in which springs have acquired an extraordinary temperature from local causes of a different kind, we hold, that their existence affords a strong indication of subterranean processes similar to those, which, on a more extended scale, gave rise to earthquakes, especially wherever we observe such a continuous and connected range of them to occur, as that which we find encircling the base of particular chains of primitive mountains, or associated with certain leading systems of elevation.

#### *Evolution of Carbonic Acid.*

There is yet another natural phenomenon closely connected with the subject of thermal waters, which remains to be considered—we mean the evolution of carbonic acid from the interior of the Earth, either alone, or accompanying certain springs.

The relation of this to volcanic processes may be established by a similar line of argument to that we have pursued in the former instance, namely, by pointing out its frequent occurrence, in conjunction with thermal waters, and in situations which have undergone certain physical convulsions.

Thus the same country, which throws out warm springs at a low level, and at a point more contiguous to the supposed focus of the volcanic action, affords cold carbonated ones at a higher level, or at a point more remote. The hot springs of Ems and Wiesbaden, for instance, are found near the base of the Taunus mountains, whilst the cold effervescing ones of Schwalbach and Fachingen occur higher up in the same chain; thus, too, the same district which gives rise to the thermal waters of Aix la Chapelle, furnishes the chalybeates of Spa near the summit of the hills above. The connection of carbonated springs with faults may be observed in Derbyshire and Yorkshire, but it has been more satisfactorily traced in Germany, where they have been found to issue from what have been termed circular valleys of elevation; that is to say, valleys which are, or appear at one time to have been, enclosed by escarpments, the strata dipping away in all directions from the centre towards the circumference. Several valleys in Westphalia exhibit this remarkable structure, and none more strikingly than that, in which the cold chalybeate of Pyrmont is situated. In this instance the rocks are composed of the variegated sandstone, the muschelkalk limestone, and the Keuper, which are seen overlapping in the hills bounding the valley, but dipping in opposite directions on opposite sides of it, so as to present every where escarpments fronting each other. (See pl. v. fig. 7.) From the bottom of the valley carbonic acid is

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constantly issuing in large quantities, impregnating the springs of water, and accumulating in dry pits and caverns. The valley of Dryburg, and other spots in the same country, noted for the occurrence of cold carbonated springs, exhibit a similar conformation in their strata.

Rullman, in his description of Wiesbaden, remarks, that in the neighbourhood of the carbonated springs which so abound in the Duchy of Nassau, the rocks are subject to remarkable changes in their dips, to saddle-shaped stratification, and to fractures. The character of the rock is also frequently more friable near the mineral springs.

Professor Buckland, in his *Memoir on Valleys of Elevation*, published in the *Transactions of the Geological Society*, had previously pointed out the occurrence of such valleys in England; and it may be worth remarking, though as an isolated fact, perhaps, not of much weight, that the most important of our chalybeates, that of Tunbridge, is found in this kind of situation.

Now the relative position of the strata in these valleys just as obviously suggests the idea of their having been affected by some convulsion of Nature, as the highly inclined rocks of Alpine Countries; and it is impossible to conceive, either that they could have been deposited in the first instance at so high an angle, and with such a variety of dips, or that there should have been such a coincidence between the elevation of their escarpments on the opposite sides of the valley, if the beds had not once been in continuity.

It may be inquired, whether even those accumulations of carbonic acid, which take place so frequently in neglected mines and wells, and which have imposed the necessary precaution of letting down a light before we venture to descend into them, may not be owing to a slow evolution of this gas from fissures beneath, in which case a volcanic action may be assigned, as, at least, its most probable cause; the law of the rapid diffusion of all gases through the atmosphere precludes the possibility of attributing it to a mere separation of carbonic acid, in consequence of its greater specific gravity, from the other constituents of the atmosphere; and the same cause would quickly dissipate it, even if it were given out by the decomposition of organic matters.

Nevertheless, before we allow ourselves to adopt this opinion, it will be necessary to ascertain, first, whether in these cases any local causes for the production of carbonic acid exist; and, secondly, whether its further generation might, in these cases, be prevented by covering the bottom and sides of the pit with some coating impermeable to air.

#### *Mud Volcanos or Salses.*

With regard to those emanations of gas and vapour, which occur in certain Countries, accompanied with eruptions of mud and petroleum, we must withhold our assent to the vulgar opinion, which attributes them to volcanic action, as the name of mud volcanos, by which they are usually designated, seems to imply.

That they are often connected with them, we are not, indeed, disposed to deny, but they appear to be so only in the relation of an effect, produced by the presence of inflammable materials, brought together by the operations of some pre-existing volcano.

That the process itself is distinct from that which takes place in the latter, is evident, from considering that

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in every case in which it has been examined, the seat of the action is found to be quite superficial, and to reside in a stratum of very recent origin, known to be strongly impregnated with sulphur and petroleum. Such is the case at Macaluba near Girgenti, in Sicily, where the mud volcanos, as they are called, lie quite detached from the true volcanic phenomena of Etna or of the Val di Noto, and seem manifestly dependent on the combustion of the sulphur, which exists in the rock in such quantities as to supply all Europe with that material.

The same is likewise the case with the "Salses," or mud volcanos of Modena, which lie at a distance from every genuine burning mountain; and, according to Humboldt, with those of New Andalusia and the Island of Trinidad. The phenomena exhibited by those in Sicily, and amongst the Subapennine Hills, are in general of a very insignificant kind, consisting of a mere evolution of water mixed with mud and bitumen in consequence of the disengagement of gas, apparently consisting of carbonic acid and carburetted hydrogen, from little circular orifices on the summit of the hill. Ordinarily, nothing but a bubbling up of gas from the interior of these craters is to be observed; but it is said, that there are times, at which the process has been known to go on with considerable energy, for the mud has been thrown up in Sicily to the height of 200 feet, accompanied with a strong odour of sulphur.

In the little Island of Taman, which connects the chain of mountains traversing the Peninsula of Crimea with the Asiatic Continent, the process in question seems to be proceeding on a more extensive scale. Pallas represents occasional eruptions as taking place from certain crevices in the rocks of this Island, which began with a thick smoke, followed by a column of flame fifty feet in height, which continued in one instance for eight hours and a half incessantly, during which time streams of mud flowed in all directions, but no lava or altered masses of stone were ejected. The accounts given by Mr. Heber, in his Manuscript Journal attached to Dr. Clarke's *Travels*, fully confirm this view, and render it highly probable, that the phenomenon is altogether analogous to that of Macaluba in Sicily, and of the Salses near Modena.

Assuming, therefore, these latter as the best types we possess of mud volcanos, and reasoning from them to the rest, it will probably appear, that all the phenomena they exhibit will admit of explanation from the mutual action of certain substances, originally accumulated in submarine solfataras by antecedent volcanic processes, the result of which would be the extrication of carbonic acid, and of an inflammable gas arising from the slow distillation of bituminous matters, together with the rise of water, through the channels originally established by the gases discharging themselves upwards. That volcanic action is not necessarily the cause, is shown by finding a similar phenomenon described as occurring in the Western States of Ohio, where it seems quite unconnected with any such cause.

In this spot the salt springs, which so abound, are found to be constantly giving rise to an evolution of carburetted hydrogen gas, accompanied with much petroleum. The jets of gas are sometimes so forcible, as to throw the water entirely out of the spring.

There seems, therefore, no necessary connection between such phenomena and our present subject, and their more frequent occurrence in rocks which lie in the neighbourhood of volcanos may be readily accounted for, by

the tendency of the latter to bring together materials proper for carrying on such operations.

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#### *Emanations of Inflammable Gas.*

Still less are we disposed to attribute to a volcanic cause the emanations of inflammable gas, which are occasionally seen issuing from the crevices of rocks, in a continued, and, according to our limited notions of time, an unfailling current.

The evolution of carburetted hydrogen from the cracks and crevices of coal mines, enables us to conceive, by what natural processes such a phenomenon may be accounted for, and the recent discoveries, with respect to the liquefaction of the gases, render the regular and lasting discharge of such a stream of elastic matter more intelligible. Now the phenomenon in question, when divested of the marvellous, reduces itself simply to this, for it is a mistake to imagine, that the flame is self-kindled, at least in the instances that have been well examined, although, when the gas is once set on fire, the supply is sufficiently regular to keep up a continued combustion.

The most noted instances of this phenomenon are at the Pietra Mala, on the summit of the Apennines, between Bologna and Florence; at a place called St. Barthlemi, near Grenoble;\* and in the Chimariot mountains in Albania, where it is probable that it has continued for the last 2000 years, for many ancient writers speak of a Nymphaeum on the coast of modern Albania, near Apollonia, celebrated for the flames that rose continually from it, and Dodwell's authority establishes the existence of the same at the present day in that country.

It is probable, that the phenomena which occur at Baku on the Western side of the Caspian, where the soil is strongly impregnated with petroleum, are connected with these last-mentioned causes, rather than with those of genuine volcanos.

There is indeed a report given of an eruption, which took place in that Province in the year 1627, but from the description it would seem to amount to nothing more, than a combustion of bituminous matters on a larger scale than usual. It is said, that a vast column of fire rose to an extraordinary height, maintaining itself at the same for three hours, after which it gradually diminished to twenty inches; the fire extended itself over a tract of ground 1300 by 1900 feet in diameter. At the time of the first eruption red-hot stones and volumes of water were ejected. No appearance of a crater was to be perceived, but the spot, whence the column of flame rose, was elevated about two feet above the general level of the plain. The surrounding tract resembles a ploughed field, and is covered with a variety of anomalous products of heat. There are, however, no ejections of water, nor any of those sulphureous exhalations, which are commonly met with in such cases, as at Macaluba, and in the other so called mud volcanos.

#### SECTION 3.

##### *Theories of Volcanic Operations considered.*

The phenomena, therefore, to which we feel warranted in appealing, as indications of igneous action going on

\* The writer of this Article visited this spot in 1830, and found that the flame rekindled when merely blown out, but that it could be extinguished by throwing water over it several successive times. The gas was collected and burnt, and water and carbonic acid were the results.

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in the interior of the Globe, are those of volcanos, earthquakes, thermal waters, and emissions of carbonic acid gas; and in order to estimate the amount of the changes that may have been brought about on the crust of the Earth by their united operation, it will be necessary to inquire with respect to the probable cause of these internal commotions, as a clew not only to guide us concerning their present action, but likewise as to the probability of their more or less extended influence in periods that have gone by.

The theories which have been propounded, with the view of accounting for the existence of volcanic action, may be divided into two classes; those which assume some chemical process, of which the heat is merely an effect, and those which, assuming the existence of the heat, deduce the other phenomena from its presence.

In the former, in short, the heat is *one* of the effects; in the second, it is the cause of *all* the phenomena observed.

The theories, however, which belong to the former of these classes, though agreeing in this one particular, that of imagining combustion of some kind to have caused the heat, differ widely as to the material which excited it; coal, petroleum, and sulphur, having all at times been assumed as the main agent concerned in the process.

But these substances have been shown, not only to be in themselves totally inadequate to explain the phenomena, but to be productive, when set on fire, of a train of effects altogether different from those of genuine volcanos; witness those arising from the accidental burning of coal mines in many parts of Great Britain, of masses of petroleum, as at Baku, or of sulphur and bituminous matters, as at Macaluba.

Accordingly it is now generally admitted, that no processes going on near the surface are calculated to produce the phenomena of volcanos; and that if the latter arise from combustion, the materials which occasion it must, in part at least, be of a different description from the combustibles which exist in a natural state within the sphere of our observation, since in order to consume oxygen without substituting for it a corresponding amount of some gaseous oxide, the products must be of a fixed nature, which is not the case in our artificial fires.

Recent discoveries have, however, convinced us, that the whole of the crust of the Earth contains principles, which in their uncombined state are in a high degree inflammable, and which, for this very reason, never occur to us, except in union with oxygen. Such are the alkalis and earths, which Sir H. Davy has shown each to contain a metallic basis, a body capable of abstracting oxygen, both from common air and from water, and giving rise at the time to a sufficient extrication of light and heat, to constitute a case of genuine combustion. There must have been a time, therefore, when these substances existed uncombined with oxygen even on the surface, and there is no reason to deny, that the process of oxygenation may still be incomplete at those vast depths, when air and water are admitted but slowly, or at distant intervals.

There seems therefore no *a priori* absurdity in imagining, that volcanic action may consist in a process of oxygenation, caused, in part at least, by the presence of these substances, and all that seems necessary, is to ascertain, how far the known phenomena accord with such an hypothesis.

The other class of theories, which assumes the high temperature, and then deduces from it the phenomena,

seems at first sight to have an advantage over the preceding one, inasmuch as the existence of an internal heat may be said to be in a manner ascertained, whilst that of the alkaline and earthy metalloids, uncombined with oxygen, is at most only probable; and accordingly many have been induced to prefer this mode of accounting for the phenomena, as less hypothetical and requiring fewer postulates.

They forget, however, that the existence of an internal heat is assumed alike on either supposition, and that the true point of dispute is, whether it can best be explained by the presence of a melted or ignited mass in the interior of the Globe, or by a process of oxygenation going on in its constituents.

Now the only distinct argument in favour of the internal fluidity of the Globe, is deduced from its figure, which has been proved to be that of an oblate spheroid; a form, it is contended, which could not have been imparted to it, had it not been originally in a liquid state, and from thence the advocates of the above hypothesis conceive themselves at liberty to infer that it is so at present.

Neither of these propositions, however, can be regarded as demonstrated. Sir J. F. Herschel has shown, in his *Treatise on Astronomy*, that the oblate figure of the Globe may only have arisen from its long continued rotation, this being the point to which, under this condition, it must tend, and which it would ultimately attain, even as its surface is at present constituted.

Neither, if we grant the Earth to have been originally fluid, is there any direct proof, that it must have continued so till the present time; for the increased temperature observed at the slight depths to which man has penetrated below the surface, only proves, that the temperature of the crust is higher than that of its superficies, not that it is considerable enough to retain the substances of which the interior is made up in a state of fusion.

The proper mode, however, of considering the question seems to be, not to lose ourselves in conjectures, as to what may by possibility be the condition of the Globe at inaccessible depths, but to pass in review the actual phenomena of volcanos, and see, whether we can best deduce them, from the mere effects of the protrusion of a melted mass of matter, or from a process of combustion, originating in materials which may still exist in an unoxidized state below.

In order, however, to determine this, it will be necessary to consider at some length, first, the geographical situation of volcanos; secondly, the character of the substances evolved by them in a gaseous state, and of the products resulting; and thirdly, that of the lavas and other matters ejected in a solid or liquid condition: from whence we shall be led to examine, the depth at which volcanic action is seated, and lastly, the mode in which the mountains are built up of materials before considered.

#### *Geographical Distribution of Volcanos.*

Volcanos are said by Von Buch, either to occur scattered at certain distances along particular lines of country, or else to be united in clusters around some common centre.

The former he calls linear, the latter central volcanos; and whilst he regards the linear, as being in general produced in the direction of the fissures caused by the igneous operations of a former period, over which the primary ranges of mountains have been upheaved, he considers the central, as taking place in all kinds of positions over the Earth's surface, however much detached they may be from any of those leading systems of eleva-

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tion, wherever the force which has been set in motion by volcanic agency is able to overcome the resistance opposed by the superincumbent rocks. In the former case the direction taken by the volcanic forces is determined by the previous configuration of the country; in the latter it takes place without reference to the nature of the pre-existing rocks.

It may, perhaps, be doubted, whether even the central volcanos enumerated by Von Buch, may not in some instances at least admit of being referred to some common system; but there can be no question, that the law which he has laid down with regard to the tendency of volcanos to burst forth in certain lines of country rather than in others, holds good very generally, and that many such groups may be enumerated; such as, that already pointed out as extending across the Greek Islands; (see pl. vi. fig. 5;) that stretching across Mexico, (pl. vi. fig. 3;) and still more remarkably the one, which, beginning at Barren Island, in the Bay of Bengal, may be traced along the Islands of Sumatra and Java, thence to the Philippines, and perhaps even to the Kurile Islands and to Kamtschatka. (See pl. vi. fig. 4.) The linear direction, therefore, of certain volcanic formations cannot be doubted; and the only question is, whether it prevails universally, or characterises, as Von Buch conceives, one particular class only of burning mountains.

#### *Proximity to the Sea.*

Another remarkable feature in the distribution of volcanos is their proximity to the sea; in proof of which it may be sufficient to remark, that out of a catalogue of no less than 163 active vents enumerated by M. Arago as occurring in various parts of the known World, all, excepting two or three in different parts of America, and about the same number, of which we possess very imperfect information, in Central Asia, are within a short distance at least of the Ocean.

It is even found, that the very excepted cases, when examined, tend to confirm the rule; being so situated, that their connection, either with the Ocean, or with inland seas that may supply its place, becomes a matter of fair inference. In proof of this we need only refer to the descriptions we have already given of Jorullo; from which it appears, that distant as this mountain may be both from the Atlantic and Pacific Oceans, it is nevertheless connected with one or both through the medium of a chain of volcanic eminences; (see pl. vi. fig. 3;) and even the volcanos of Tartary, whose existence in an active condition is more problematical, may be connected with some of those extensive salt lakes, which seem to abound in the depressed portion of Central Asia.

Thus even those few cases, which may be brought forward as exceptions to the general rule, appear, when examined, to enter into it, so far as relates to the probable connection they denote with deep seas or lakes; whilst the occurrence of by far the majority of active volcanos in Islands and maritime tracts, and their entire absence from many extensive Continents, may convince us, that the processes are at least greatly promoted by such a position, and in their intensity bear a certain relation to the more or less ready access to them of water.

And, although extinct volcanos seem by no means confined to the neighbourhood of the present seas, being scattered often over the most inland portions of our existing Continents; yet it will appear, that at the time at which they were in an active state, the greater part were in the neighbourhood of those extensive salt or fresh-

water lakes, which existed at that period over much of what is now dry land. Instead, therefore, of these being brought forward as exceptions to the generality of the rule, the cessation of such action, now that the water has left their neighbourhood, seems to furnish a confirmation of its truth.

#### *Aeriform fluids evolved.*

We have next to consider the ordinary products of volcanic operations, and shall begin by noticing the aeriform fluids evolved, regarding them as in a manner the prime movers of the effects we witness, the agents, by whose mighty power are propelled from the bowels of the Earth those solid matters, afterwards to be described, which, settling round the brim of the orifice from which they found an issue, grow at length into the form and dimensions of an ordinary crater of eruption.

During the active condition of a volcano, the aeriform fluid most copiously emitted probably is steam, which manifests itself in those white vapours which usually proceed from the crater during an eruption, and may assist in producing by its condensation the heavy rains which frequently succeed it, though we are more disposed to attribute these to the disturbance in the electricity of the atmosphere, which is evinced by the vivid lightning commonly observed during a volcanic eruption.\*

Steam is also emitted, sometimes for ages together, from fissures called "stufas," on the flanks of many extinct as well as active volcanos; thus supplying us with a confirmation of the dependence of volcanic phenomena upon the presence of water.

The permanently elastic fluids commonly given out are, muriatic acid, sulphuretted hydrogen, sulphurous acid, carbonic acid, and nitrogen.

Of these the first, muriatic acid, seems to be generated during almost all the phases of volcanic action; for although some have attempted to establish a class of volcanos to which the production of muriatic acid was peculiar, yet it would seem that they were none from which this gas is not in greater or less quantity disengaged.

Thus it has not only been detected by Sir H. Davy, issuing from the flanks of Vesuvius soon after the eruption of 1815, but likewise from the same mountain whilst in a more quiescent condition in 1824.

It was also found by Professor Dauberty, in the vapours given off round the crater of the Island of Volcano, round that of Etna whilst dormant, and in that of the Solfatara of Puzzuoli; it has been discovered also in the volcanos of Iceland; in those of Java, at Mount Idienne; and of South America, at Puracé, accompanied in both these latter cases with a predominant proportion of sulphuric acid; nay, it has even been found in an uncombined state pervading the trachytic rock of the Puy di Sarcouy in Auvergne. Of the gaseous compounds of sulphur, one, the sulphurous acid, appears to be predominant chiefly in volcanos possessing a certain degree of activity, whilst the other, sulphuretted hydrogen, seems to be emitted for the most part when they are in a dormant condition.

\* Sir H. Davy, in his Memoir on Vesuvius, remarks that it was easy, even at a great distance, to distinguish between the steam disengaged by one of the craters, and the earthy matter thrown up by the other. The steam appeared white in the day, and formed perfectly white clouds, which reflected the morning and evening light of the purest tints of red and orange. The earthy matter always appeared as a black smoke, forming dark clouds, and in the night it was highly luminous at the moment of the explosion.

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Thus sulphurous acid is given off in large quantities from the craters of Etna and Vesuvius, and even from that of Volcano in the Lipari group, whilst sulphuretted hydrogen is observed at the Solfatara of Puzzuoli, on the skirts of Etna near Jaci Reale, and in many hot springs connected with dormant volcanic action both in these regions and elsewhere.

Not that we are obliged to suppose sulphurous acid to be entirely absent in the latter cases, or sulphuretted hydrogen in the former; for as these two gases, when they meet, decompose each other, forming water and depositing sulphur, it is reasonable to expect, that only that portion of either which exceeds the quantity necessary for their mutual decomposition will escape from the orifice, so that the gas that actually appears, only indicates the predominance of the one, and not the entire absence of the other.

Carbonic acid appears to be chiefly found in volcanos that have become extinct, and when it occurs in those considered active, it is at a time when they are not in a state of eruption. It is also found to occur more commonly at the foot and in the neighbourhood of volcanic mountains, than in their craters, or at the points of their most vehement action; so that it may be viewed, rather as one of the consequences of a long continued operation of the heat produced upon the contiguous rocks by volcanic processes, than as the direct effect of the processes by which that heat is occasioned.

The last of these gases, nitrogen, has been already sufficiently alluded to: from the observations hitherto made, it would seem to be for the most part the concomitant of languid volcanic action; but it is probable, that, when the gases evolved from active volcanos have been scrupulously examined in a greater number of cases, it will be noticed much more commonly as occurring amongst them; since Sir H. Davy detected it, in Vesuvius, and his brother Dr. John Davy, in the gas given off by the new volcanic Island near Sicily, in both cases accompanied with less than the usual proportion of oxygen.

#### *Substances not gaseous ejected.*

Other substances are often disengaged from volcanos as vapours, but condense round its exterior either in a liquid or a solid condition.

Such is the petroleum found by Breislac, at the foot of Vesuvius, the Val di Noto in Sicily, the extinct volcanos of ancient Latium and Auvergne, the site of the ancient eruption recorded in the Book of *Genesis* on the spot now occupied by the Dead Sea, and many other localities. Such also is the sulphuric acid, which has been only hitherto met with in extinct volcanos; as for instance in a stream issuing from that of Purace between Bogota and Quico, from one derived from Mont Idienne in Java, and probably in the rocks connected with the languid operations about Radicofani in Tuscany. It is obviously derived from the sulphurous acid, which, passing through the water of some volcanic lake, and absorbed by it, has derived an additional dose of oxygen from the atmospheric air present.

The solid substances sublimed by volcanos are, 1. the boracic acid, found in the crater of Volcano, and the Lagunes of Tuscany, which, though it remains fixed in our furnaces, appears to be evolved in vapour by the heat of these volcanos. 2. Muriate of ammonia, very abundantly evolved during certain eruptions, as by that of Etna in 1780, but apparently absent from others.

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3. Specular iron ore, probably disengaged in combination with chlorine, which latter principle may be separated, on its coming into contact with the atmosphere, by means of the heat, water, and oxygen of the air. 4. Muriate of soda, the most abundant of them all, as well as the most universal; being exhaled more or less by almost all volcanos, and present even in their lavas, according to Monticelli, who obtained more than nine per cent. of it, by simple washing, from that which issued from Vesuvius in 1822.

We do not include among the sublimations, the deposits of sulphur, or the sulphurets of iron, copper, arsenic, and selenium; still less the various sulphuric salts found efflorescing in the spiracles of all volcanos.

The sulphur, which seems to be of almost universal occurrence wherever volcanic operations are going on, is evidently derived, in the majority of instances, from the mutual decomposition of the sulphurous and sulphuretted hydrogen gases; for we know of no well authenticated case of its sublimation in an uncombined state from any volcano, and analogy would lead us to extend the same inference, to the compounds of sulphur with arsenic and selenium, that occasionally accompany it.

The sulphates of lime, alumina, iron, magnesia, and soda, which so frequently incrust the surfaces of recently ejected masses, or the fissures of volcanos in present action, are evidently produced, by the affinity exerted by the sulphuric acid, which has proceeded from the sulphurous acid disengaged, for those alkaline and earthy bases with which it may have come into contact.

The substances hitherto considered, in whatever condition they may present themselves to the eye of the observer, have evidently been either disengaged from the volcano in a gaseous form, or at least have resulted from the same; but we have next to consider those, which have been thrown out in a solid or a liquid state from the crater, but without becoming, like the former, volatilized by the action of the heat.

#### *Solid Substances ejected.*

They may be divided, into such as have undergone a complete change from the process, amongst which we comprehend lavas, and loose ejected masses of similar composition; and such as are thrown out, either unaltered, or at least retaining enough of their original characters, to be identified with some one or other of the existing rocks.

#### *Lavas.*

##### *Their Chemical Characters.*

Beginning with the former class of substances, I shall first state the chemical, and afterwards the mineralogical characters of lavas.

Lava, when observed as near as possible to the point whence it issues, is, for the most part, a semifluid mass of the consistence of honey, but sometimes one so liquid as to penetrate the fibres of wood. It soon cools externally, and therefore exhibits a rough unequal surface; but, as it is a bad conductor of heat, the internal mass remains liquid, long after the portion exposed to the air has become solidified. The temperature at which it continues fluid is considerable enough to melt glass and silver, and has been found to liquefy in four minutes a mass of lead of such a size, as, when placed on red-hot iron, to require double that time to enter into fusion.



Stones of a spongy nature, pumices probably, were melted when thrown into the lava of Vesuvius; that of Etna is said to have effected the same; and a current, which proceeded from an Iceland volcano, is stated to have melted down every kind of hard stone that came in its way.

On the other hand, masses of limestone have been taken out from the midst of lava with no signs of fusion upon them, and even with their carbonic acid undiminished; and the houses of Torre del Greco, and of other villages, which have been enveloped in liquid lava, remained unmelted by it. When bell-metal was submitted to the action of the Vesuvian lava of 1794, the zinc was separated, but the copper continued unaffected.

Sir James Hall, in his Memoir on Whinstone and Basalt, has presented us with a Table of the relative fusibilities of seven specimens of whin or basalt from the neighbourhood of Edinburgh, and of an equal number of lava from various European localities; from which it appears, that when converted into the state of glass, they become softened at a temperature from  $15^{\circ}$  to  $24^{\circ}$  of Wedgwood, or  $3027^{\circ}$  to  $4197^{\circ}$  of Fahrenheit. Whilst in a crystalline state, the same ingredients continued solid at this temperature, but became soft at one varying, from  $24^{\circ}$  to  $55^{\circ}$  of Wedgwood, or from  $4717^{\circ}$  to  $8227^{\circ}$ , a heat inferior to that of a common glass-house.

With this statement regarding the melting point of these ignigenous products, the chemical composition, which appears to belong to them, is in complete accordance.

According to Dr. Kennedy, two specimens of the lava of Mount Etna contained each 4 per cent. of soda, and nearly 15 of oxide of iron, to 51 of silex, 19 of alumina, and about 10 of lime. Other lavas, doubtless, are differently constituted, and some appear to be completely destitute of alkali; yet even in these latter cases the presence of some alkaline earth, capable of acting as a flux to the silex and alumina, seems universally to supply its place; and accordingly, there are few varieties, that do not readily fuse at the heat of an ordinary blast furnace, and some, indeed, at a much lower temperature.\* Nevertheless, there are circumstances, which have induced certain Naturalists to adopt quite a different view of the nature of lavas, and to imagine them to owe their fluidity, not to the intensity of the heat, but chiefly to the presence of some solvent or flux.

This opinion was originally broached by Dolomieu, who founded it upon the assumption, now admitted to be erroneous, that the crystals of augite and hornblende which lava contains, existed antecedently to the fusion of the mass, and were not produced in consequence of it. Hence he necessarily concluded, that the lava could only have been subjected to a degree of heat, inferior to that at which such crystals would become fused.

Finding, therefore, sulphur to be exhaled from certain lavas, he imagined this to act as a flux to the other substances, and accounted for the more difficult fusibility of the mass when once cooled, from the escape of the sulphur originally present. The existence of sulphur in lavas has been asserted by some, and denied by others, but whether it be present or not, there seems no necessity for attributing to it the fusion of the mass, when, as we have seen, its composition alone sufficiently accounts for this circumstance.

\* According to Saussure, *Journal de Physique*, an. 2, felspar melts at  $70^{\circ}$  of Wedgwood, basalt at  $76^{\circ}$ , and hornblende at about  $100^{\circ}$ .

It must in any case be disengaged very soon after the melted matter has been ejected, for no sulphurous vapours are perceived to issue from a lava current of old standing, even though it may continue internally fluid; and it is well known, that sulphur forms no part whatever of the composition of lavas, and can, therefore, only be mechanically mixed with them.

A recent Geologist has lately brought forwards a modification of Dolomieu's theory, by supposing water to act the part which the latter attributed to sulphur; and although we are compelled to reject his theoretical views on this subject, as utterly inconsistent with known chemical principles, yet they suggest some interesting inquiries, with respect to the state in which those volatile matters existed in lava, which are said to be copiously disengaged from it in the state of vapour. Have they been confined by the pressure of the superincumbent mass, until its gradual cooling caused fissures by which they were enabled to make their escape, or is it possible, that the influence of pressure may be assisted by some kind of chemical union between them and the other constituents? All writers admit, that various salts are emitted from the surface of recent lava, which are never found amongst its constituents; and if these are sublimed, as appears to be the case, by the heat, the same may also happen with regard to the other more volatile matters, whose extrication from lava is vouched for on respectable authority.

#### *Their Mineralogical Characters.*

The mineralogical characters of lavas have been already given at the commencement of this Article, where they are stated to belong in general to the rock called by Mr. Scrope greystone, and by M. Brongniart tephrite, consisting essentially of felspar, with many accidental ingredients superadded, such as olivine, mica, augite, hornblende, titaniferous iron, and the like.

#### *Loose Fragments ejected*

The loose fragments ejected from the crater differ but little in mineral composition from the continuous streams of lava, but they are generally of a more cellular and porous aspect, not uncommonly fibrous, and consequently more brittle and incoherent. They also frequently present that vitreous appearance which is the effect of sudden cooling, and vary in size from masses many tons in weight to a fine and impalpable powder.

There seems, therefore, good reason for suspecting, that all those volcanic products which we have just been considering, in whatever form they may have issued from the volcano, are allied to the rock denominated trachyte; and, that they are either derived from it, or, at least, formed out of the same materials as those of which the latter is composed, appears from our finding, that, in many places where the structure of a volcanic mountain has chanced to be exposed, the lowest in the series of formations that present themselves to the eye is of a trachytic nature, and that the strata superincumbent often seem to show a resemblance to that rock, more or less close in proportion to their contiguity to it.

#### *Trachyte, whence derived.*

Trachyte, also, is a rock of such universal occurrence in volcanic Countries, and so abundant in those in which the action is of the most remote date, and has taken place on the most extensive scale, that it seems to be natural to derive the lavas subsequently ejected from it,

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regarding them merely as so many modifications of this original material, more or less changed by the larger continuance of the heat, or the admixture of other matters.

But, considering the peculiar characters and composition of trachyte, as well as the circumstance of its being limited to Countries that appear to have undergone the action of volcanic fires, we can hardly regard it as a substance which makes a part of the original constitution of the Globe, and shall be disposed to set it down, as itself a product, although a primary one, of the fusion of other kinds of rock. Of what nature this latter may consist, will, perhaps, be determined, if we examine, first, with what particular descriptions of rock trachytes are most connected in point of situation; and secondly, to what they present the nearest resemblance in mineralogical and chemical composition.

The former inquiry will lead us to consider, in the first instance, the nature of those ejected masses which appear to belong to the contiguous rock formations, and not to be products of the igneous operations to which their ejection has been owing.

Among these, we read of no substance bearing the slightest resemblance to the constituents of secondary or tertiary strata, but of many which may, with the greatest probability, be referred to rocks of a granitic character.

Thus at the Puy Chopine in Auvergne, granite is found intermingled with the trachyte and greenstone, thrown together in confusion, as if the whole had been elevated at one time, before the rock had been entirely changed by the process.

In the lavas of the Vivarais, in those of the Rhine, and in other localities, unbedded masses have been met with, having much the appearance of an altered gneiss or granite. Humboldt mentions his having found, in the midst of the new volcano of Jorullo in Mexico, white angular fragments of syenite, composed of a small portion of hornblende, with much lamellar felspar; Gemellaro discovered a mass of granite containing tinestone amongst the ejected masses of Mount Etna; and the same rock has been discovered amongst the trachyte of the Ponza Islands by Mr. Scrope, and in the lava of Vesuvius by Dr. Thomson of Naples.

Mica slate has, in one instance, been found ejected by Vesuvius, and various granular limestones of a dolomitic character are found amongst the masses ejected from the old crater of Vesuvius, which lie accumulated in the Fossa Grande, and other hollow ways on the slope of the volcano. It must be remarked, however, that these latter are never imbedded either in the lavas or in the volcanic masses ejected, so that they do not stand in the same relation to them, as the granitic masses do which have been before enumerated.

With regard to the formations, in which trachytic rocks, or, to speak more generally, volcanos, usually appear, great discrepancy seems at first sight to exist.

Thus, to begin with the Rhine, the formation on which the trachyte of the Siehengeberge rests, and among which the volcanos of the Eifel have arisen, is a clay slate belonging to the transition series; in Auvergne, the rocks of Mont Dor and of Clermont rest immediately upon granite, or are separated from it only by a tertiary deposit, whilst those of Cantal are incumbent on mica slate. In Hungary the rock underneath is a porphyry, associated with syenite, clay slate, &c. and referred by Beudant to the transition series; in Transylvania, according to Boudé, the trachytes lie near the

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mica slate and gneiss, with which are masses of syenite and marble; whilst in Styria, the rock most immediately surrounding the little trachytic formation of the Gleichenburg, is gneiss.

In Italy the case is somewhat different; yet, though the trachyte of the Euganean hills rises from beneath chalk, we have reason to believe that primitive and transition rocks lie at no great depth beneath, as they are found near Schio, and support the alternations of volcanic and neptunian deposits in the Braganza.

Humboldt has shown, that the rock which supports the volcanos of the New World is generally a transition porphyry, and sometimes granite or syenite; and Von Buch reports, that the last-named rocks appeared as the lowest of those uplifted strata, which surrounded the crater of the Island of Palma and other of the Canaries. Now, although the preceding enumeration indicates such a variety with regard to the position of volcanic formations as may seem at first sight to baffle all general conclusions; yet when we consider, that, in the majority of instances, the rocks have been referred either to the primitive or the transition series, and that in the remaining ones, the latter were at a depth far less considerable, than that at which we shall afterwards find reason to conclude, that the volcanic force itself resides; it may not be unfair to presume, that volcanos have universally broken out amongst the older formations, or those most near to the nucleus, whatever that may be, of the Globe.

It is obvious, indeed, that in those cases in which volcanos have appeared in the midst of primitive rocks, we cannot presume the seat of action to reside amongst those of a later date, but that the converse does not hold good; so that if we only admit, that any certain position is to be assigned to these products, a single case of their occurrence in the midst of older formations would overturn every inference to be derived, from their being observed to emanate from strata of a more recent date.

The legitimate deduction from the above facts are, moreover, strengthened by considering the mineralogical and chemical constitution of trachyte, both which bear such a resemblance to that of granite, that the rock has been called by Dolomieu granitoid lava.

And although the two rocks may be distinguished, by the presence of quartz in the one, and its absence from the other, yet the predominance of felspar in both seems to place them in the same genus, and to distinguish them from the constituents of secondary strata, where that mineral hardly can be said to occur, except where we have reason to suspect the agency of fire.

It is probable, too, that the chemical composition of granite and trachyte taken from the same localities, would not be found to vary materially, notwithstanding the differences in their mineral constitution pointed out.

Thus, though quartz is wanting in trachyte, and abundant in granite, yet the silicious earth contained in that mineral, may have united with the alumina present, in such proportions as would form felspar, and in this manner the latter may have become more abundant, at the expense of the other two ingredients of the granite.

In some cases, on the contrary, when the material operated upon consisted chiefly of quartz, the result may have been that variety called millstone trachyte, which, though chiefly silicious, betrays its igneous origin by the cells and cavities it so abundantly contains.

If, then, there be reason to conclude, that the substance, which has supplied the materials ejected by



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burning mountains, or constituting their internal nucleus, be derived from granitic rocks, a strong argument will be afforded, in favour of the great depth at which the operations are seated, that have given rise to the effects we witness.

This inference, indeed, is greatly strengthened by a consideration of the phenomena attendant on an eruption, the general tenour of which plainly denotes, that the focus of the action is situated at a depth at the least as great, as that to which granite may be supposed to extend.

We do not, indeed, lay any stress on the remarks of Stukeley, who calculates from the compass of country over which earthquakes have been felt, that the force must, in some instances, be 200 miles beneath the surface, because we have seen reason to believe, that vibrations may be propagated laterally beyond the immediate influence of the impelling force; but we would argue, from the immense mass of materials ejected by any one volcano, as for instance by Etna or Vesuvius, without exhausting itself, or causing any sinking of the mountain; from the prodigious height, to which the trachytic nucleus of others seems to be raised, as at Teneriffe and in Equinoctial America; and, lastly, from the immense violence of the eruptions, which would shiver into pieces any merely superficial covering of rock, that the elastic vapours must be disengaged at a depth at least as great, as that to which the crust of the earth can be supposed to extend.

#### *Constitution of a Volcanic Mountain in general.*

Having now examined the products of subterranean fire individually, we will next consider them in the aggregate, and explain the manner in which they produce those vast accumulations of volcanic materials, which occupy so large a portion of the surface of our Globe.

Those observers, who have been fortunate enough to obtain a near view of the crater of a burning mountain, in what is called its active condition, inform us, that the interior of it is filled with a body of melted lava, which may be seen alternately rising and falling within the chasm. At its maximum of elevation, one or more immense hubbles have been seen to form on the surface of the lava, and rapidly swelling, to explode with a loud detonation. This explosion drives upwards a shower of liquid lava, which, cooling rapidly in the air, falls in the form of scorix. The surface of the lava is in turn depressed, and sinks several feet, but is propelled again upwards in a moment by the rise of fresh volumes of elastic fluids, which escape in a similar manner. Such is the account given by Mr. Scrope of the crater of Stromboli, which he surveyed from a commanding point of rock; such likewise in the main is that given by Spallanzani of Etna, by Bory St. Vincent of the volcanos of the Isle of Bourbon, and by Ellis of Kiranea, in Owhyhee. In all these cases, a mass of melted matter, of unknown depth, covered for the most part with a thin pellicle of scoriform lava, and emitting copious volumes of steam or gas, was observed in the crater which they overlooked.

Now it is evident, that the tendency to eruption in all these cases will depend upon the relation existing between the expansive energy of the materials and the controlling force, derived, in part, from the pressure of the superincumbent atmosphere or ocean, and in part, from the weight of the column of liquefied matter; and as in

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general a considerable proportion of the matters ejected during a paroxysm of volcanic action falls back into the crater, whilst the elastic fluids, which served to expel them, escape, the active state of a volcano will in these cases be intermittent, and its eruptions placed at distant intervals asunder.

In a few rare instances, as at Stromboli, where, from some peculiarity in the configuration of the mountain, the whole of the ejected materials falls into the sea, and is carried away by a strong current to a distance, the repressive and expansive forces may be so equally balanced, that a series of explosions shall occur at short intervals, for any length of time during which the volcanic processes continue, without any accession of violence ever taking place, sufficient to produce the emission of a continuous current of lava. In cases where the opposite forces are so nicely balanced, it may happen, as Mr. Scrope has ingeniously suggested, that the mere variations of atmospheric pressure would cause a difference in the explosive force, and thus may explain, what the inhabitants of that Island are said to have remarked, that the intensity of the eruptive violence is greatest in stormy weather.

#### *Craters of Eruption.*

It is evident, then, if we suppose this to be the condition of every active volcano, that, when once the violence of its operations has arrived to such a pitch, as to overcome the resistance opposed to it, the elastic vapours will throw out portions of the liquid lava, just as, when a mass of melted metal happens to fall into a vessel containing water, the steam generated disperses it in all directions. These portions of lava projected into the air, descend again in the form of scorix or sand, and collect into an aggregate, which is called, rather improperly perhaps, a bed of volcanic tuff.

But the projection of these fragments is soon followed by the overflow of the melted lava itself, which by degrees reaches the brim, spreads over the tuff, and forms a regular bed encircling the original aperture.

Now the repetition of these successive operations would cause just that alternation of beds of lava and tuff, which is found to constitute the sides of most volcanic craters, and it will be at once seen, that the direction in which they lie, to appearance horizontal, when viewed from the interior of the chasm, but in reality dipping on all sides away from the centre at an angle of about 30°, is exactly what would happen, if we suppose them formed in the manner represented. In plate v. fig. 9, the disposition of the beds in a crater of eruption is given, and, as contrasted with it, is shown that of the beds on a hill, which may chance to have been hollowed out by the action of water, in a manner, which causes it to correspond in external appearance with that belonging to the crater, after the latter has been broken away, and partially destroyed, by the agency of other causes.

It is true, that we can hardly imagine many hundred alternations of strata so constituted to mantle round the crater in the way supposed; for it is evident, that the slightest irregularity in the brim over which the lava flowed, or upon which the scorix descended, would determine these materials more on one side than the rest, so that we should never find, after the first few beds had been formed, any that actually extended round the whole circumference.

But Professor Lyell has stated from actual observation, that this appearance of uniformity is deceptive, and

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that the cone is in reality composed of a number of beds, each of which thins out so gradually, as to be confounded, and to appear continuous, with some other placed next it.

#### *Craters of Elevation.*

The above statement of the ordinary succession of phenomena occurring during a volcanic eruption, which we owe originally to M. Neckar de Saussure, supplies us with a very simple and natural explanation of the structure of an ordinary volcanic cone, the quaquaversal dip of its strata, the regular alternation of tuff and lava, and even perhaps of the dykes which intersect them. But are we at liberty to infer that the whole of a volcanic mountain, whatever may be its form, antiquity, or position, whether situated, like Vesuvius, on the borders of the sea, or like the Peak of Teneriffe in the midst of a fathomless ocean, is built up entirely after this fashion?

Even in the absence of any direct evidence on the subject, we should be inclined to hesitate before we adopted such a conclusion, and to ask ourselves whether, under so enormous a pressure as that of the Ocean, the expansive force of elastic fluids, struggling to escape, would not be more likely to upheave in the first place the strata nearest the focus of the action, when softened by the heat, within a given area, than to eject fragments of rock round a cone in the manner represented.

We might also feel perplexed to explain on such a supposition the appearance of any detached volcanic mountain in deep water, since such materials, if accumulated under the sea, would be too quickly diffused over its bottom, to raise the level to any considerable height at one particular point.

It would also seem, that if earthquakes are allowed to have brought about an occasional upheaving of the Earth's surface, and that, without producing such a confusion of the strata affected, as even to interfere with the springs of the country, or to throw down the buildings erected on the spot, there would be still greater reason for attributing the same effects to volcanic action exerted upon rocks which have been actually softened by the previously existing heat.

But independently of these probabilities, there are not wanting direct proofs of the upheaving of rocks, that appear to be connected in some way with volcanic operations; proofs derived, in some cases from the appearances they present, and in others from the actual testimony of eye-witnesses.

#### *Upheaving of Volcanic Mountains shown,*

##### *First, by their own appearances.*

The former are drawn from the examination of volcanic mountains, whose interior structure is from some cause or other in such a manner exposed to view, as to reveal to us the real nature of the material which composes its nucleus.

Thus in the Island of Great Canary, and still more remarkable in that of Palma, a chasm called the Caldera exists, nearly 4000 feet in depth, which afforded to Von Buch an excellent section of the internal structure of the mountain itself. Lowest of all he discovered the primitive rocks, then masses of trachyte, and above various alternations of those volcanic strata which usually occur in craters. The latter, for ought we know, may have been formed by successive

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ejections of lava and scorise; but the trachyte and the granite underneath must have been upheaved, for why else do we find them at a height, which, though 4000 feet perhaps from the summit, is at least 3000 from the base of the mountain, and consequently from the level of the sea, and that sea too unfathomable? Can we resist the belief, that at least the granite with its superincumbent trachyte were upheaved from the bottom of the Ocean by volcanic agency, and thus constituted a nucleus, round which the subsequent ejections have taken place? Ought not such an example to be regarded as more conclusive, than the observations of a contrary tendency which other Geologists have recorded, with respect to the appearances presented in some of those deep valleys, which exhibit sections of the interior of the volcano?

Where, as in the case of the Val de Bove on Mount Etna, the structure is similar to that, which at present results from the eruptions, that from time to time take place, we have doubtless a right to assume that they were produced in a similar manner, and consequently the antiquity of the volcano is enhanced, in proportion to the extent of the series of strata so exposed; but we are not therefore entitled to conclude, that the original formation of the volcano must have been of the same nature with that of its subsequent growth, still less to extend the same inference to other volcanos that may appear differently constituted.

##### *Secondly, by the Existence of Domes of Trachyte.*

Of the upheaving of trachyte in detached dome-shaped or conical masses, and that by forces which we can hardly hesitate to regard as volcanic, examples, we conceive, of even a less equivocal kind, may be found, in Countries more accessible to the European traveller.

To what other cause, for example, are we to attribute the occurrence of those five isolated hills of domite, which we meet with near Clermont in Auvergne, the largest of which, the Puy de Dome, rises nearly 3000 feet above the general level of the plateau on which it rests?

On what possible supposition are we to account, for the regularity of their form, their perfectly detached position, and their occurring, each in the midst of an amphitheatre, composed of volcanic rocks of a totally different kind? Shall we imagine them to be the relics of a continuous stratum, once spreading over the adjacent country, but since removed by subsequent changes? or shall we suppose them to be masses of a kind of lava, which, from its imperfect fluidity, accumulated round a central point, without spreading into the adjacent plain? The former supposition seems irreconcilable with the fact of the total absence of all traces of the rock elsewhere, and with the conical form belonging to some of these masses; the latter is manifestly inconsistent with its chemical constitution, and the idea of its owing its fluidity to intense heat, which we have thought fit on other grounds to adopt.\*

In one of these hills, the Puy Chopine, we appear even to be able to trace the very steps by which the process has taken place. We observe here, not merely a rock composed of that variety of trachyte, which in the

\* See this question more fully discussed in a Letter to Professor Jameson, on the Diluvial Theory, and on the Origin of the Valleys of Auvergne, by Professor Daubeny, published in the *Edinburgh New Philosophical Journal* for April, 1831.

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other four hills constitutes the whole mass, but by the side of it, forming the side fronting the South-west, South-east, and East, a congeries of various primitive and volcanic rocks in different states of alteration. We may enumerate, a conglomerate of scorix and volcanic tuff, of basalt, hornblende slate, sienite, and granite, more or less disintegrated, especially where in contact with the trachyte. The whole of the mountain is surrounded by an amphitheatre of rocks composed of a congeries of scoriform volcanic products, from the midst of which it appears to have been elevated; so that we seem to have at once presented before our eyes, the material from which the trachyte was elaborated, the several steps in the process of change effected, and the mode in which, when so prepared, it was made to occupy its present position.

If, however, we believe Humboldt, the New World must present a much more decisive instance of the kind, than the Puys of Auvergne we have been just considering; since Chimborazo, the highest mountain in that hemisphere, is represented by him, as composed entirely of trachyte, and being, both in form and composition, on the great scale, what the Grand Sarcouy in Auvergne is on a smaller one.

Now we may remark, that it is only because these mountains, owing to the shifting of the volcanic fire to another quarter immediately after their elevation, or to some other peculiarity in their physical condition, have given rise to no ejections of lava or scorix, that we are enabled to ascertain so decisively their constitution; for had they assumed the character of permanent vents, and consequently been covered, as Etna and Vesuvius are, by a numerous succession of layers of volcanic materials, we should then have been induced to conclude, that they were entirely built up of that, which constituted in reality merely their external superficies.

There are also not wanting instances in volcanic districts, where the ordinary rocks of the country have been heaved up round a circumscribed area, evidently by the expansive force of vapours from beneath, so as to form crater-shaped cavities, resembling in all particulars, except in their component parts, that assumed by a volcano. Mr. Scrope himself has described one of them in page 74 of his *Memoir on Central France*, where he makes mention of a circular lake called *Le Gour de Tazana*, about half a mile in diameter, and from thirty to forty feet deep. Its margin, for a fourth of the circumference, is flat, and elevated above the valley into which the lake discharges itself. Every where else it is environed by steep granitic rocks, thickly sprinkled with small scorix and puzzolana, and rising about 200 feet from the level of the water. These fragments are all that indicate the volcanic origin of this gulf-like basin, but they are sufficiently decisive. No stream of lava, or even fragments, of any large size, are perceivable.

Similarly formed craters occur likewise in the Eifel; and perhaps the best example of them is the circular volcanic lake called the *Meerfeld*, hollowed out of transition slate and red sandstone, without any admixture of volcanic matter, though surrounded by loose fragments of augitic lava. Now if we admit, that in these instances, the rocks in question have acquired their actual position from the operation of expansive vapours acting from below, what reason is there for questioning the possibility of the same forces having acted likewise upon volcanic strata, and caused them to be upheaved in a similar manner?

Even limestone rocks, if we believe Von Buch, have sometimes been elevated by volcanic agency in a conical

form, so as to imitate in their appearance the trachytic masses mentioned as occurring in Auvergne.

Instances of this kind are met with between Trent and Roveredo, and it is remarkable, that the rock in every case is of a dolomitic character, whereas the limestones in the neighbourhood are destitute of magnesia. The same remark applies, as we have seen, to the ejected masses of granular limestone found at Vesuvius, which are dolomitic, although the apennine limestone of the neighbourhood is in general not magnesian.\* (See pl. iv. fig. 7. 8.)

Hence Von Buch has had the boldness to attribute this latter ingredient to the volcanic action, imagining the Earth in question to have penetrated the volcanic matter whilst in a liquid or pasty condition, so as to form with it a chemical compound.

There are, it must be confessed, weighty difficulties in the way of such a supposition, and in some of the spots which Von Buch has appealed to in proof of his theory, as, for instance, at Gerolstein in the Eifel, the circumstances are such as to preclude us from adopting such a supposition, without a manifest anachronism;† nevertheless the singular appearances of these rocks, and their connection with the surrounding strata, have induced many to suspend their judgment, and to regard the impregnation of limestone with magnesia, in the manner supposed, as one of those facts, which a more advanced stage of chemical knowledge may explain, or at least render more conceivable.

Even those who reject this theory of Von Buch's, will hardly hesitate to regard the curved stratification, manifested not unfrequently in our sections of the Earth's surface, as caused by an upheaving force. We are indebted to Mr. Bakewell for presenting us with an instance, which seems to comprehend all the conditions requisite for establishing this view of the case. Four miles East of Matlock, in the isolated hill called *Crick Cliff*, about 900 feet above the Derwent, the strata rise in all directions towards the central point, so as to form nearly spherical segments. (See pl. i. fig. 6.)

The true structure of the hill has been discovered by recent mining operations, several valuable metallic veins having been explored in it, and a gallery driven in it, as represented in the figure.

Now it is obvious, that, although the inclination of plane strata may result from subsidence, such an arched structure as that represented could hardly have been formed except by protrusion, of which its proximity to beds of toadstone, to which we ascribe a volcanic origin, suggests an explanation. In this instance, however, we are not left to conjecture; for lately, in driving the gallery on towards the centre of the hill, a mass of toadstone was met with; and the same was found, by sinking a shaft from the top of the hill, so that the cause and the effects are at once displayed, in the section we are enabled to give of this hill.‡

\* In fig. 7. is an ideal section by Von Buch of the rocks in the Val de Fassa, Tyrol, showing the manner in which he conceives the pyroxenic porphyry to have first heaved up and displaced the shelly limestone, together with the other rocks, and afterwards to have converted it into those masses of dolomite which cap the summits of the overhanging mountains.

† In fig. 8. a drawing is given of one of these dolomitic mountains; and the position of the porphyry, the shelly limestone, and the red sandstone with reference to it, is indicated by the annexed figures.

‡ See Daubeny, *Description of Volcanos*, p. 53.

§ See Bakewell, *Geology*, 1833.

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But if the appearances which are presented by many of the rocks affected by volcanic fire lead to a conclusion favourable to the notion of their having been uplifted; still more decisive is the evidence afforded us by those persons, who have either been eye-witnesses of the formation of a volcano in a new site, or have been situated, nearest in point of time or place, to the theatre of such events.

Father Gorce, in 1707, was eye-witness of the appearance of a new rock, between the two Islands of Great and Little Cammeni, off Santorino in the Grecian Archipelago. He states, that it gradually increased in size and in height, until it became half a mile in circumference, and rose twenty or thirty feet above the level of the sea, bringing up with it live oysters. After this had happened, a crater appears to have been formed, from which fragments of volcanic matter were ejected, and the latter now cover the surface of the Island, and conceal the underlying rock.

Among the Aleutian group, Langsdorf has described a rock near the Island of Unalashka, 3000 feet in height, consisting of trachyte, which made its appearance in 1795, and seems to have been thrown up at it once from the bottom of the Ocean. The Island that has recently appeared in the Mediterranean between Sicily and the African coast, though the part elevated above the sea was made up of scoriaform matters disposed in concentric layers round a central orifice, seems below to have consisted of an upheaved mass of rock. It is certain, at least, from Captain Smyth's account, that the depth of the water on the site of the Island was at least 100 fathoms, when he sounded it in 1814; and it appears from the chart accompanying Dr. Davy's Paper, that it varies in the immediate vicinity of the Island from 1 to 12 fathoms, from whence it gradually increases, so that at a distance of from 100 to 200 yards from it, the present soundings are from 20 to 65 fathoms.

Now this change of level may no doubt be explained in two ways; either by the gradual accumulation of scoria and other volcanic products, or by the more sudden elevation of a portion of the bed of the Mediterranean. With either hypothesis the structure of the crater is equally compatible; for it is natural to suppose that, after a conical mass had been upheaved, ejections of scoria might have taken place round a central point.

But with regard to the mode in which the operations of the volcano began, we are disposed to give the preference to the hypothesis of a sudden upheaving; for to have raised the bed of the sea from 100 to 10 or 12 fathoms water, would seem to require a longer continuance of volcanic operations than is noticed as having occurred on this spot, as well as a wider dispersion of the ejected masses over the sea than appears to have been the case. We hear indeed of scoria and ashes having been distributed in all directions, even to the coast of Sicily, but we do not find any sensible difference in the level of the sea recorded, excepting within an area of one or two hundred yards round the Island, from which central point, therefore, the sea appears to sink abruptly in every direction.

*Phenomena of Jorullo.*

Lastly, Humboldt has presented us with an instance, where, in the centre of the great table land of Mexico, and at a period not more distant than the middle of the last Century, both the descriptions given by the inha-

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bitants of the country, who were actual eye-witnesses of the event, and the appearances exhibited at the time the spot was visited by himself, led him to the conclusion, that a large tract of ground from three to four square miles in extent was heaved up in a convex form to the height of 550 feet, and that from the midst of this protuberance arose six conical hills, the least of them 300 feet in height, and the loftiest, Jorullo, elevated 1600 feet above the level of the plain.

Certain English Geologists have lately questioned the soundness of this explanation, and have suggested that the convexity of the plain may have been produced by a simultaneous overflow of lava from the six cones, and that these, uniting into one sheet, may have formed a sort of circular pool or lake of lava.

But this solution seems to us clogged with still greater difficulties than that offered by Humboldt; for although it be true, that the viscosity of a lava current is such, that we ought not to suppose it subjected altogether to the same laws as those which regulate the flowing of a body of water, still it seems probable, that some trifling inequality of surface in the plain over which it has spread, some variation in the quantity of lava given out from the different orifices, would determine the sheet of lava to one point rather than to another, and thus produce a stream flowing in a given direction, instead of a lake of melted matter circumscribed within so definite an area.

It has been said, indeed, that the heaving up of a tract of land of this kind is unprecedented; but so, it may be replied, is the formation of such a convexity, by the mere overflow of a stream of lava proceeding from any existing volcano. And it must moreover be recollected, that, according to the very conditions of the theory advocated by those Geologists who have objected to Humboldt's views on this point, our historical records would embrace so very small a portion of the time occupied by any of the great physical revolutions of our Globe, that there appears the less reason, for circumscribing Geological reasoning strictly to the data obtained by actual observation, provided it assumes nothing inconsistent with the laws which the latter tend to establish.

Thus we have literally no record of any other volcano formed in a new site upon land, than this of Jorullo; for the throwing up of the Monto Nuovo near Naples can be regarded in no other light, than as a transference of the volcanic action, which is taking place at the Solfatara, or at Vesuvius, to another neighbouring quarter.

It may also be remarked, that the existence of a hollow space beneath a volcano, which may be accounted for, although it does not necessarily follow, from the uplifting of the rocks composing its nucleus, seems the best and most obvious means of explaining the phenomenon stated by Dr. Horsfield to have occurred in Java; where the mountain Papendayang, formerly one of the largest volcanos in the Island, is said to have given way, and in part to have fallen in, so that an extent of ground, fifteen miles long and six broad, was swallowed up in the bowels of the earth, with the destruction of forty villages and a large proportion of their inhabitants.

There seems, therefore, good reason to believe, that volcanic rocks have been heaved up, both in the sea and on land, by the expansive force of elastic vapours, a position of greater importance in a theoretical point of view than might be at first anticipated, seeing, that it justifies us in applying these same forces to the explanation of the more extensive elevations of mountain ranges,

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of which Geology apprizes us, though, as of the elevation of cones of trachyte, history is silent concerning them. Now a belief in the elevation of isolated masses of rock may serve to reconcile us to certain opinions, with respect to the origin of volcanic craters, which, resting as they do on the authority of the two individuals, who have examined volcanos, on the most extensive scale, and under the greatest variety of aspects, deserve from us at least a patient and unprejudiced hearing.

#### *Craters of Elevation.*

Von Buch has distinguished the craters of volcanos into two classes: those produced by eruption, and by elevation. The former are brought about in the manner already pointed out by Neckar de Saussure and others, and are found in all volcanos which have given rise to currents of lava, or have constituted permanent vents of volcanic materials.

The latter are produced, owing to the upheaving of the crust of the Earth by the agency of elastic vapours round a certain limited area, and may, therefore, consist either of the older rocks of the country, or of the products that have been accumulated by antecedent volcanic operations. The one may be illustrated by the crater of Meerfield in the Eifel, and that of the Tour de Gazana in Auvergne; of the latter (the Puy de Dôme) and other conical masses of trachyte afford, as we conceive, unexceptionable examples.

Now as the structure of a crater of eruption has been compared by Professor Lyell to that of an exogenous tree, which increases by layers deposited from without; so that of a crater of elevation may, to follow up the same analogy, be perhaps compared to that of an endogenous one, where the growth is caused by the protrusion of a mass from within. The question, therefore, is, in what way are we to determine whether a given crater, or, to speak more generally, a given volcanic formation, be the result of the one or of the other process?

And here we must refer to an excellent Memoir lately published by Messrs. Elie de Beaumont and Dufrenoy, who adopt the following method of distinguishing between the two.

When the sides of the mountain are covered with bands of lava circumscribed within narrow limits, we may fairly infer that they have been formed by successive ejections; when, on the contrary, the whole circumference of the cone is covered by a continuous sheet of volcanic matter, which is commonly the case where the substance of it is basaltic or compact, we may presume that it has once been nearly horizontal, and has since become upraised. The former may happen most commonly in those volcanos which are subaerial and at present in action, but the latter is the case generally in those which are subaqueous.

If we suppose a body of liquid lava to be ejected from the bottom of a deep sea, and consequently under the pressure of a considerable volume of water, a crust would quickly form over its upper surface, in consequence of the rapid abstraction of heat by the water immediately superincumbent; so that the lava subsequently ejected would be compelled, by the resistance opposed by this hard, unyielding mass to its progress upwards, to spread itself laterally in all directions; thus forming a sheet or tabular mass of lava extending over the bottom of the sea on which it was poured out.\*

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Now it is evident, that an explosion of gas taking place underneath a mass of lava, such as that represented, might produce a crater of elevation, by heaving up the lava round a given area, and producing a central cavity, through which the elastic vapours and solid matters ejected might continue to escape.

Messrs. Elie de Beaumont and Dufrenoy appeal to the elevated table lands of Mont Dor and Cantal, as affording instances of elevation, but as being altogether irreconcilable with the doctrine of craters of eruption; and it is certain, that if the sheets of trachyte are really continuous, we will not say over the whole of these mountains, but over any considerable portion of them, the notion of their being caused by successive ejections from a number of distinct craters, must be renounced as untenable. M. Virlet, indeed, one of the most distinguished opponents of the elevation theory in France, who accompanied the scientific expedition sent by the French Government to the Morea, is compelled to admit, that the eruptions, which built up the Mont Dor and the Cantal, must have been on a greater scale than any which we at present experience; thus giving up the very point which pleads most strongly in favour of the rival theory, by admitting, that causes now in action, operating with only their present intensity, are inadequate to produce the phenomena. On the other hand, the adversaries of Von Buch's theory in this Country, more consistent in their opposition, endeavour to show, that lava currents of equal extent have been produced in modern days; and doubtless Iceland, and even Sicily, afford examples, which may be fairly brought into competition with those of more ancient date.

But Messrs. de Beaumont and Dufrenoy contend, with great appearance of justice, that it is only when the lava has reached a tract of nearly level land, that it spreads itself over so wide a surface as is there represented, and that during its descent down the sides of the volcano it is almost invariably circumscribed within a very limited area.

When, therefore, we observe a conical hill composed of sheets of lava or trachyte, which can be ascertained to be continuous round the whole or the greater part of its circumference, we must suppose it once to have been horizontal, and afterwards to have been heaved up into its existing position.

Von Buch has, however, extended his theory to such craters as that of the Islands of Palma and of the Great Canary, assuming that all the strata observed in looking down from the summit of the Caldera have been upheaved, and that this deep chasm has been formed in consequence.

The Caldera of the Isle of Palma, says Von Buch, differs from a crater of eruption in many striking particulars. Here are no streams of lava, no slags, no lapilli, or ashes. Nor do we ever find the latter of such a circumference, or so profound and abrupt. Its general aspect seems to show, that it was formed by the pressure of those elastic fluids, which raised the whole Island above the level of the Ocean, and changed the strata composing it from an horizontal to their present highly inclined position. The aspect of those narrow and precipitous ravines, called Barancos, which encircle it, favours this hypothesis. They are so circumstanced, that we can hardly attribute them to the action of water; but if we suppose a succession of solid and unelastic strata to be suddenly lifted up in the manner of those in the Island of Palma, it is evident that not only would a central

\* See Delabache's *Manual*, third edition, p. 125.

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aperture be formed where the crater now exists, but that the strain would occasion a number of lateral fissures corresponding with those called in the Island *Barancos*.

To those, indeed, who have hitherto derived their notions on these subjects exclusively from English sources, we would recommend the perusal of the great Work on the Canary Islands, which we owe to the Prussian Geologist above mentioned. We shall there find a record of phenomena, which seem hardly reconcilable to that theory with regard to the building up of volcanic mountains by the successive ejections of beds of scoriae and lava, which, from its seductive simplicity, is calculated in a manner to preoccupy the mind of the Geologist.

We shall there see whole islands formed, of beds of basalt, not of scoriae or of tuff, preserving in their external circumference a circular form nearly as perfect as that of the brim of their central crater, towards which they on all sides incline. We shall then see, in the midst of this amphitheatre, of basaltic rocks, and of other materials, which could scarcely have been formed excepting under water, a conical mass of trachyte rising to a great height with a crater in its centre,\* and this crater one, which has not in all cases emitted lava currents or scoriae, but has served only as a vent for steam or gases. Now, if these appearances can be best explained by an upheaving of rocks previously formed beneath the bed of the Ocean, what arguments of a general nature can be alleged to prevent us from adopting such a conclusion, seeing, that we are only extending to the materials of a whole island, what all admit with respect to certain isolated rocks; imagining that to have taken place in Palma, and the Great Canary, which we have almost been eye witnesses of at the Islands of Santorino and Sciacca; proceeding, as it appears to us, legitimately, from the observed consequences of earthquakes at present, to the inferred effects of similar forces at periods antecedent?

That the hypothesis in question may have been pushed too far, and that some of the followers of Von Buch, originally misled by his authority, may have since been obliged to retrace their steps, is nowise improbable; but this does not invalidate the truth of the facts, which he and others have alleged, as applicable to the cases of Teneriffe, or Jorullo, or oblige us to imagine all volcanoes, in whatever quarter of the Globe they may be, to be built up, after the model of those few on the borders of the Mediterranean, which chance to be most accessible to Europeans.

We hold, in short, that it would be just as illogical to argue, that because many craters have been built up by the gradual accumulation of successive eruptions, therefore that the same must have been the case with all, as to contend, that because the trachyte which forms the bottom of the Caldera has been uplifted, therefore that the strata superimposed upon it must have been so likewise, without reference to their nature or contents.

Both descriptions of crater probably have a real existence in nature, and the business of the Geologist, therefore, is to distinguish the one from the other, by a particular examination of each, and by considering, whether the strata that compose it have most the appear-

ance of submarine lavas, or of the products, which are seen forming under our eyes by subaerial volcanoes.

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We have been disposed to dwell the more upon this theory of Von Buch, conceiving that justice has hardly been done to its pretensions by English Geologists, partly, in consequence of the original papers, in which his views were promulgated, having never been translated into our language, and partly, in consequence of their being somewhat at variance with certain doctrines in this Science, prevalent at the present time amongst us.

If, however, we may presume to act as arbiters between this great German Geologist, and his opponents in England, we should say, that the latter are perfectly justified in referring to processes of which they have duly experience, those craters to which both theories may be applicable, on the very same principle, on which we have ourselves given a preference to the simpler hypothesis advanced by Professor Forbes, and since so ably advocated by Mr Lyell, to account for the phenomena of the Temple at Puzzuoli, (see p. 717.) though we have seen nothing to convince us, that the more complicated theory advanced by Goethe would not likewise account for them. On this principle we do not doubt that Hoffman has done right in retracting his original opinion with respect to Mount Etna being a crater of elevation, though we have yet to learn that this concession on his part ought to be construed into a general abandonment of Von Buch's theory as applied to other cases. On the other hand we would submit to our readers, whether, on reviewing the facts that have been put before them, they will not conclude, that the objections raised against the possibility of such cases occurring, as Von Buch has exemplified in his Work on the Canary Islands, rest on too narrow a view of volcanic phenomena, which, in order to be complete and satisfactory, ought to embrace the phenomena observed in Equinoctial America, as well as those of Europe; the extinct volcanoes of Auvergne, as well as the recent ones of Naples and Sicily; and which, at least, should admit of being applied to all cases of upheaving, whether occurring in primary ranges of mountains, in the so called valleys of elevation existing amongst newer deposits, or in tracts of confessedly igneous origin.

#### SECTION 4.

##### *Theory of Volcanic Operations.*

Having now treated in succession the different phenomena found to accompany volcanic action in its various phases of intensity, we may, perhaps, be in some degree prepared to estimate the relative probability of the two modes already mentioned, by which its existence has been accounted for.

We say, the relative probability of the two, for after all, there will be few so wedded to either, as not to contemplate, new volcanic phenomena being brought to light, fresh principles in Chemistry becoming recognised, which may give a preference to some third explanation, entirely different from either of the foregoing, seeing, that one of those conditions laid down by Lord Bacon as requisite in order to guarantee our belief in a theory, namely, that the cause assigned should be ascertained to have a real existence, can be, predicated neither of the one nor of the other.

We would also remark, that the real question at

\* The drawing of the cone and crater of Barron Island, Bay of Bengal, pl. iv. fig. 4. will give some idea of what is here described.



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issue between the advocates of the rival theories, stated in its broadest terms, is simply this,—whether the phenomena of volcanos seem to imply a process of oxidation or not, if they do, then our acquaintance with bodies which are kindled by the mere contact of water, enables us to explain the manner in which the process of combustion may originate, its continuance becoming a matter of subsequent consideration; whilst, if the facts before us can be accounted for merely by assuming the presence in the interior of the Globe of a mass of melted matter, we should scarcely be disposed to go further for a solution of them.

Now the progressive refrigeration of a ball of melted matter proceeding from its circumference towards its centre, would doubtless produce something like an imitation of one volcanic phenomenon, namely the emission of lava currents, since the contraction of the crust upon its internal contents would squeeze out from time to time, at the points of least resistance, a portion of liquid matter proportionate to the gradual diminution of its capacity.

We may also understand, why the points of least resistance should often be on the coasts or in the depressed portions of continents; why the action of the volcano should in general be intermittent, and why it should continue for centuries without becoming exhausted.

We might also account on this hypothesis for the volumes of carbonic acid emitted, regarding them as resulting from the action of the heat upon the constituents of the limestone rocks placed within the sphere of its operation, and consequently as being unconnected with any process of combustion.

But, on the other hand, this hypothesis does not explain, why volcanos should break out in the middle of the sea, where the pressure must be greater, than it is on continents, intersected as the latter are with caverns and fissures; why it should take place in certain lines of coast only, and not generally, wherever there be low land, and why, if as they would be from an inexhaustible fountain of liquid matter, they should ever become extinguished, or at least, continue dormant for no very extended a period, as to convey to us that impression.

Neither does this hypothesis explain the differences that exist between the products of volcanos, which, if derived from the same internal source ought perhaps to be uniform in their composition and structure.

In conceding, therefore, that the conditions of this hypothesis permit us to explain this phenomenon, it is conceived, that we have gone further than we are strictly warranted in doing; whilst with regard to others more characteristic and essential than even the emission of lava, it leaves us altogether in the dark.

In what manner, for example, will the admission of Cordier's theory enable us to account for the evolution of steam, and of the different gases, which we have seen to be constantly present, or for the consequences of the confinement of these elastic fluids in the interior of the Earth, which manifest themselves, in the explosions that accompany an eruption, or in the upheaving of rocks and the production of earthquakes which we attribute to its operations?

Nor can we be considered guilty of any gratuitous assumption in thus attributing them, for, although the upheaving effects of volcanic action have been by some ascribed merely to the hydrostatic pressure of a mass of lava, which had been forced up to the summit of the crater, yet it is plain, that to have brought it into that position in defiance of the laws of gravity, some powerfully

moving force must have been required, and what force can be suggested, at once so probable in itself, and so adequate to the effect brought about, as the evolution of a great body of elastic vapour, the existence of which we are compelled from many other considerations to admit?

Aware probably of the difficulties that suggest themselves to Cordier's theory in this its most simple form, many of those who profess to support it, call into play another principle, namely the action of water, which, making its way to depths where the Earth is supposed to maintain a temperature sufficiently exalted for this purpose, is converted into steam, and thus serves by its elastic force to eject the various heated matters which issue from the orifice.

It must be confessed, that such an addition to the theory supplies us with an explanation of much, which former view of it had overlooked, especially, the situation of volcanos near the sea, their power of upheaving rocks, and in general the expansive force, which constitutes one of their leading features.

Yet even here, unless we suppose some kind of combustion to take place, we are left in the dark, with regard to the evolution of sulphurous acid and of nitrogen gases, and unless we suppose the existence of some principle or other capable of decomposing, as well as of converting into vapour, the water that finds admission, we shall hardly be able to account for the steady and copious emission of hydrogen combined with sulphur, which has been noticed.

It may, indeed, be said, that sulphurous acid would arise from the spontaneous union of sulphur with oxygen, at the high temperature to which it would be subjected, if it existed so deep in the bowels of the Earth; and that several of the commoner metals, such as iron, are capable of decomposing water, and combining with the oxygen of the atmosphere, when subjected to the same heat—whence would result an evolution, both of sulphuretted hydrogen and of the residuary nitrogen, derived from the atmospheric air admitted.

But when the naturalist is once brought to allow, that combustion of some kind or other makes a part of volcanic operations, he will necessarily look to the products of these latter, in order to satisfy himself, what the materials may have been which have contributed to the effects.

Now we have already seen, that the substances ejected from the crater of a volcano usually consist, in the largest proportion of siliceous matter, next of alumina, then of oxide of iron, then lime, and lastly soda or potash.

That the elements of these bodies must, some of them at least, have absorbed oxygen from the atmosphere, during the process by which their fusion has been effected, seems to follow, from the nitrogen disengaged, and the ammoniacal salts sublimed; and if we are thus brought to admit, that a metal so oxidizable as iron may exist in its metallic condition at these depths, what is to hinder us from going one step further, and applying the same supposition to the bases of the earths, and alkalies, thus obtaining a readier solution of the energetic character of those processes, which are adequate to produce the effects we witness?

It has, indeed, been alleged, that the two principal constituents of lava, namely, the bases of silica and alumina, are not highly inflammable. Silicon, when perfectly pure, resists a white heat without uniting with oxygen, and stannic acid may be boiled in water without decomposing it. But, in the first place, it is rare to

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ment with these oxides, without finding them accompanied either with lime or an alkali; and the basis of the former, we have reason, from Davy's experiments, to believe, is highly inflammable; the latter we know to be so. Secondly, silicon kindles readily if united with a little hydrogen or with carbonate of soda; and aluminium even by itself burns brilliantly when heated to redness, and dissolves with the evolution of hydrogen in very dilute solutions of potass.

There is, therefore, no difficulty in imagining the combination to be kept up by means of the silicon and aluminium, when once it has been commenced by the action of water, upon the potassium, sodium, or calcium present.

It has also been objected, that hydrogen gas is never emitted from the spiracles of any volcano, as if it were not quite natural, that it should be evolved in union with sulphur, when generated in places so abounding in that material.

That the quantity thus emitted has been enormous, will appear from this consideration alone, namely, that the immense beds of sulphur in Sicily are probably derived from certain submarine solfataras, and that in solfataras the sulphur which is deposited arises, not from the sublimation of that solid, but from the deposition of it by the sulphuretted hydrogen and sulphurous acid disengaged which, when they come into contact, mutually decompose each other.

It is not clear, also, that hydrogen gas may not be evolved likewise in combination with carbon, and even with phosphorus, since the flame, which has been represented as rising from the ground both during earthquakes and volcanic eruptions, indicates the former; and the bubbling up of gas, through the sea, which inflamed on coming into contact with the air, a phenomenon observed near the Azores, would seem to imply the latter.

At all events, a large proportion of the hydrogen emitted may be presumed to make its appearance in the ammoniacal salts disengaged, and a still larger proportion to be recombined with the oxygen of the atmospheric air present, and to appear as steam.

The above hypothesis has this further recommendation—that it accounts for the intense action, which appears to be kept up in some cases without intermission for a considerable period, although it must be supposed to be taking place in caverns, or confined spaces deep in the bowels of the earth.

Had the combustion been of such a nature, as to give rise only to some gaseous product, such as carbonic acid, the combustion would soon have been suspended, or at least checked, by the predominance of a principle so destructive to flame, as we find to be the case in coal mines that have caught fire. Nor would the result have been different, if sulphur, or even phosphorus, had been the sole materials by which the combustion was maintained, for in either instance an atmosphere would have been produced, in which the further oxydation of these bodies could not have proceeded.

But, supposing the substances inflamed to be metals, which form with oxygen a fixed product, and disengage from water an inflammable principle, as in the case assumed, we can see no reason, why the combustion might not continue for ages with unabated vigour, as is the case in several volcanoes.

An objection against our hypothesis has also been sometimes deduced from the mean density of the Earth, which is calculated at five times that of water; and hence it has been concluded, that bodies so light, as

potassium and sodium are, cannot make a part of its nucleus.

But we are not obliged to imagine a larger proportion of these alkaline bases to be present, than would be implied by the composition of the lava emitted, and probably we shall find, not more than four or five per cent. of potass or soda to exist in the average of volcanic productions.

On the other hand, the specific gravity of the basis of silica, and, probably, also, of that of the other earths which predominate in lava, is sufficiently considerable to warrant the conclusion, that a mass of matter, containing these principles in the proportions indicated, and united with as much metallic iron, as we know to exist in the state of an oxide in the generality of lavas, would form an aggregate possessing an higher specific gravity, than that of the compound resulting from the oxydation of the entire mass.

Let us take, for instance, the analysis given by Dr. Kennedy of the lava from Etna, which he states to consist of

Silica ..	52 per cent	× Sp gr 2.65	= 127.8
Alumina ..	19 per cent	× Sp gr 4.20	= 79.8
Lime . . .	10 per cent	× Sp gr 3.00	= 30.0
Oxide of iron	15 per cent	× Sp gr 5.00	= 75.0
Soda . . .	4 per cent	× Sp gr 2.00	= 8.0
	100		320.6

We here find that 100 parts of this lava have a specific gravity equal to 320.6, and consequently that the specific gravity of the mass would be no more than 3.2, supposing it divested of water.

Now let us contrast this with the specific gravity of 100 parts of the metallic principles, which would give rise to a mineral possessing the above chemical composition.

Silica . . .	52 contains of base 26	× Sp. gr. 2.0	= 52.0
Alumina .	19 contains of base 10	× Sp gr. 2.0	= 20.0
Lime . .	10 contains of base 7	× Sp gr 4.0	= 28.0
Oxide of iron	15 contains of base 12	× Sp gr. 7.8	= 93.6
Soda . .	4 contains of base 3	× Sp gr 1.0	= 3.0
	100	58	196.6
Now is 58 - 196 = 100 = 340.			

Consequently the specific gravity of the whole would be no less than 3.4. The specific gravity of aluminium appears not to be ascertained, but probably it is not inferior to that of silicon, which sinks in the strongest sulphuric acid, and therefore is more than 1.93.

The theory therefore, we have been advocating, leaves the question with respect to the cause of the Earth's density just on the same footing as before. Those who are of opinion, that the latter may be explained by the mere condensation of such rocks as are found near the surface, in consequence of the superincumbent weight, as certain metals may be rendered heavier by pressure, are entitled to extend this explanation to the case of the alkaline and earthy bases, whilst those who regard the density of the Earth to be a proof, that some heavier matter must exist below, are not precluded from such a supposition, as our theory implies merely the existence of such a quantity of metallic ingredients, as would be sufficient to produce the materials ejected, leaving the constitution of the remainder just as open to conjecture as it was before.

It is curious, indeed, that whilst some have argued, that the kind of materials found near the surface is



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inadequate to account for the density attributed to the Earth in general; others, as the late distinguished Professor Leslie, have contended, that these substances would have their specific gravity so much increased by the enormous pressure, that void internal spaces must be necessarily supposed. On this he has founded his singular hypothesis, that the centre of the Earth is filled only with light, the rarest substance known; an idea, the mere mention of which is sufficient to show, how little we can be justified in rejecting an explanation of facts, merely because it appears to militate against the conjectures, that may be conjured up with regard to the internal condition of our Planet.

Dismissing, therefore, this objection, and leaving to our readers full liberty to form their own conclusions with respect to the internal state of the Globe, granting even to such as contend for it, that an internal fluid mass might give rise to some of the phenomena of volcanos; we conceive, that if the opposite theory can explain other effects, which the above leaves untouched, in addition to those which it elucidates, we are bound by every rule of sound reasoning to allow it the preference.

Now that this is the case, we shall attempt to show, by deducing, from the supposed existence of the alkaline and earthy metalloids at a certain depth in the Earth, the several phenomena of volcanos, in the order in which they present themselves.

#### *Statement of the Theory proposed.*

We will suppose, that the nucleus of the Earth, at a depth of three or four miles, either consists of, or contains as a constituent part, combinations of the alkaline and earthy metalloids, as well as of iron and other more common metals, in the proportions indicated by the composition of lava; these being combined, perhaps, with sulphur, and constituting various sulpho-salts. Such bodies are gradually undergoing decomposition, wherever they come into contact with air and water, but, defended by the crust of the Globe, as even a mass of potassium of a certain size may be by a crust of its own oxide, if kept perfectly dry, the chemical action excited goes on too slowly to produce any of its more striking effects, unless the latter of these agents be present in considerable quantity. Hence, under our continents, the elastic fluids generated, and the heat evolved, show themselves principally, in their influence on the temperature of the interior, or in the phenomena of thermal waters.

But under the sea, or in any other situation where the pressure of an equally large column of superincumbent fluid assists in forcing the water through the crevices of the subjacent rocks, the action must often go on more rapidly, and the effects consequently wear a more formidable aspect.

These latter, however, will occur in the middle of the sea less generally than on the coast, because the pressure of the Ocean itself furnishes an impediment to the escape of elastic fluids, greater than that of the contiguous land, and they will in general not be constant but intermittent, because the heat generated by the process itself will have a tendency to close the orifice by which the water entered, first, by injecting the fluid lava into the fissure, and secondly, by causing a general expansion of the rock; nor will the water again find admission, until, owing to the cessation of the process, the rock becomes cool, and consequently again contracts nearly to its original dimensions.

Now the first effect of the action of water upon the

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alkaline and earthy metalloids would be, the production of a large volume of hydrogen, which will either combine with oxygen (supposing atmospheric air to be present) or with sulphur, both being at the high temperature favourable to their union. In the former case, nitrogen gas will be given off, and this, expanded by the heat, will rise towards the surface, either in its free state, or combined with a portion of the hydrogen in the form of ammonia, which, however, will be neutralized by the free muriatic acid, the strongest usually present. Hence the sal ammoniac, so frequently found in volcanos, and the nitrogen given off in hot springs.

The hydrogen not thus disposed of, combining with the sulphur, will form sulphuretted hydrogen gas, which, for the same reason, will rise upwards in a gaseous form, unless it be decomposed by union with oxygen, or in any other way.

But so long as oxygen be present, in sufficient quantity to combine with the hydrogen, and re-convert it into water, the sulphur will continue in combustion, and consequently sulphurous acid will be predominant amongst the gaseous exhalations emitted from the mouth of the volcano.

So soon, however, as the oxygen is consumed, the hydrogen, no longer entering into combustion, unites with the heated sulphur, and escapes in the form of sulphuretted hydrogen, which consequently, towards the close of the eruption, when the oxygen is expended, will predominate.

As, however, the two gases alluded to mutually decompose each other, the appearance of sulphuretted hydrogen from the mouth indicates, not necessarily the entire absence of sulphurous acid at the place where the process is going on, but its less copious production than before, owing to the more scanty supply of oxygen.

The very circumstance of the reproduction of water, by the mutual decomposition of these two gases, might be the means of keeping up the action in a languid manner for an indefinite period.

The slowness with which lava cools, would cause it to go on giving out, for a considerable time, sufficient heat to the adjoining strata, to communicate to the sulphur the temperature necessary to occasion its combination with oxygen; hence, a certain portion of sulphurous acid would be continually emitted, which, however, would be soon decomposed by the hepatic gas present. The water resulting from this process would percolate into the recesses of the rock, attack any portions of the alkaline and earthy metalloids that might have escaped the original action, and give birth to a fresh volume of hydrogen gas, ready in its turn to dissolve a new portion of sulphur, and thereby to contribute to a repetition of the same phenomena. Thus, no diminution in the quantity of water present on the surface of the Globe need arise from even an endless repetition of volcanic processes, a comparatively small portion of that fluid fulfilling the same office in these great natural laboratories, which a little nitre discharges in an oil of vitriol manufactory; the same water serving over and over again as the carrier of oxygen to whatever metallic matter is capable of decomposing it, just as the nitrous gas generated by the nitre furnishes oxygen to the sulphurous acid, owing to its previous conversion into nitrous acid vapour.

The separation of muriatic acid from the common salt and other muriates present in sea water, is explained on the common principles of chemistry, by the superior affinity exerted by the alkaline base at these high temperatures for the silicious or aluminous earth, than for the

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acid; and the sublimation of iron, in the state of ferruginous oxide, rather than in that of a peroxide, may have resulted from the deoxygenizing property of the sulphuretted hydrogen, at the same time disengaged.

The carbonic acid is probably derived from the action of the heat on the calcareous strata contiguous, and is consequently given off even by volcanoes that appear extinct, owing to the long continuance of the heat, or the languid action going on long after the tendency to eruption has ceased.

All the phenomena, in short, which are concomitant upon volcanic action, seem to admit of explanation, if we will only suppose salt-water, and afterwards atmospheric air, to find admittance to cavities in the interior of the Earth, where they can come into contact with the metals, and the earthy or alkaline metalloids, combined with sulphur, there existing; and if it be objected, that the presence of air in the interior of a volcano, in sufficient quantity, seems problematical, we may reply, that as the first effect of the heat would be to produce a softening of the contiguous strata, it must necessarily happen, that the evolution of so large a portion of elastic matter would have the effect of bearing them up to a certain distance round the focus of the volcanic action.

This aperture would undoubtedly be occupied in the first instance by the gases given off by the volcano itself; but the slightest intermittence, or even inequality in the process, would occasion a partial vacuum, which the air of the atmosphere would immediately fill.

We may fortify these conclusions by the authority of Sir H. Davy, who in a *Memoir on the Phenomena of Volcanos*, published in the *Philosophical Transactions* for 1824 remarks, that there was every reason to suppose in Vesuvius the existence of a descending current of air, that the subterranean thunder heard at such great distances underneath the mountain, is almost a demonstration of the existence of great cavities below, filled with aeriform matter, and that the same excavations, which in the active state of the volcano throw out during so great a length of time immense volumes of steam, must, there is every reason to believe, in its quiet state, become filled with atmospheric air.

Hence, perhaps, we may explain a phenomenon that has been noticed during the continuance of an eruption, namely, that of the air being heard to rush through the various spiracles of the mountain, with a loud, and as it is represented, an almost musical sound.

Notwithstanding, therefore, the respect we entertain for the authorities, both in this Country and on the Continent, which, in discussing these two theories, appear to have thrown their weight into the opposite scale, we are still disposed to prefer the chemical one just laid down, to that which, in contradistinction to it, we shall venture to denominate the mechanical one.

Not one of the supporters of the latter view has, so far as our information extends, attempted to do that, which alone can exalt an hypothesis, from the rank of a mere vague suggestion of the fancy, to that of a rational and satisfactory solution of a physical problem: none of them has undertaken the task of taking up, one after the other, the phenomena that have been observed to occur during the different stages of volcanic agency, and showing their respective agreement with the principle laid down at the commencement.

This we have at least endeavoured to accomplish in the foregoing pages; and until the same shall have been effected by the advocates of the rival theory, we must be

excused for adopting that view, which, even if less simple, we are at least entitled to consider for the present more adequate to embrace all the conditions of the problem to be solved.

Neither should it be forgotten by those who object to our views, on the ground that the existence of the metallic bases of the earths and alkalies in the interior of the Globe is imaginary, that it is likewise that of their own fundamental postulate—the mass of melted matter in the interior of the Globe which they assume; whilst the high temperature belonging to the crust of the Earth, wherever it is out of reach of atmospheric changes, so far from affording any independent proof of their position, would be an almost necessary consequence of such chemical processes as those in which we suppose volcanic action to originate.

## PART II.

### DESCRIPTION OF ROCKS, ATTRIBUTED TO VOLCANIC ACTION TAKING PLACE UNDER CIRCUMSTANCES DIFFERENT FROM THOSE BEFORE CONSIDERED.

#### SECTION I.

##### On Trap Rocks

##### Introduction

Having now concluded our intended sketch of the phenomena of existing volcanoes, and attempted to explain the causes from which they originate, we have to consider in the next place, the influence which they may have exerted on the condition of our Planet, the rocks that have been produced by their operations, or altered in character and position by their agency.

It is this part of the inquiry, which connects the subject of volcanoes with the other investigations of Geology, and renders their study of interest, not merely to the Chemist and the Natural Philosopher, but likewise to all who would attempt to explain the condition, past or present, of the Globe we inhabit.

We shall begin then, by considering the rocks, which, though differing in some respects from those produced by volcanoes at the present day, appear to us nevertheless, to be derived from the same cause acting under somewhat altered circumstances.

There are few parts of the World, that do not offer examples of those rocks, which are comprehended by Geologists under the name of trap, including, as it does in its most extensive signification, on the one hand, basalts, greenstones, syenites, and wacke, and on the other, porphyries with base of felspar or claystone. To each of these general subdivisions are annexed sundry mechanical aggregates, in which pebbles or angular fragments of the rocks above mentioned constitute the prevailing ingredients.

##### Basalt

The first of these, basalt, appears to be an intimate mixture of compact felspar, either with hornblende, with augite, or with both. It is sometimes of an uniform texture, but more commonly contains imbedded crystals of olivine, augite, felspar, and titaniferous iron ore.

Its decomposition seems to give rise to the substance called wacke, a rock of a dull earthy appearance, and a dark greenish or reddish colour, which, when it admits of being examined, appears to be composed of augite or hornblende, with felspar, altered from the effects of weathering or other causes.

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*Greenstone.*

The rock called greenstone is a granular aggregate of those minerals, which in basalt are so intimately mixed, as to be undistinguishable by the naked eye. It, therefore, consists essentially of felspar, either with augite or with hornblende, but the predominance of one or other of the two latter minerals over the felspar, communicates to the general mass that greenish colour from which its name is derived. Thus the term hornblende includes both the rock denominated diabase, and that called dolerite, by Brongniart; it may also comprehend, in a Geological sense, the hypersthene rocks noticed by Dr. Macculloch in Sky, and other parts of Scotland, where the mineral called hypersthene takes the place of the augite or hornblende which generally belongs to it.

*Syenite.*

Syenite differs from greenstone rather in the proportion, than in the nature of the minerals that compose it. It consists essentially of felspar and hornblende, but the greater predominance of felspar imparts to the mass a lighter colour. Quartz is also a frequent ingredient, and mica sometimes occurs imbedded.

*Claystone Porphyry.*

Syenite, therefore, forms the connecting link between this class of trap rocks and the second, where the basis is either of felspar or claystone, which latter is probably only a more earthy and disintegrated condition of the former mineral, bearing the same relation to compact felspar, which wacke appears to do to basalt. The crystals, which impart to this rock its porphyritic character, are necessarily of felspar, but others are often imbedded, such as quartz, mica, augite, or hornblende. Where the basis is claystone, the rock is called claystone porphyry; where it consists of compact felspar, the name of felspar porphyry is applied to it.

In other cases, it consists of that slaty and splintery species of felspar, denominated clinkstone, and then is usually known by the name of clinkstone porphyry.

More rarely the porphyritic structure is not discernible, in which case the rock is called simply, claystone, compact felspar, or clinkstone, according to the nature of its constitution.

With this, or the foregoing class, are sometimes associated other rocks, which appear, from the analogy of their structure and chemical composition, to have been formed by similar natural processes.

Such are the hypersthene rocks above noticed; and to this same denomination appear to belong the serpentine rocks which occur in primitive, transition, and even in secondary formations. Serpentine seems to consist of an intimate mixture of the mineral termed diallage, with felspar; and, when it occurs in a granular condition, constitutes the gabbro of the Italians, or the euphotide of Brongniart. It, therefore, bears the same relation to the latter, which basalt does to greenstone.

*Pitchstone.*

Another rock belonging to this series is pitchstone, which either consists wholly of the mineral so denominated, or of a basis of that mineral with crystals of glassy felspar, by which it is rendered porphyritic.

It may, perhaps, be considered, rather as a particular form or condition of felspar or basalt, than as a distinct

substance, holding to these minerals a relation similar to that which obsidian does to lava.

There ought, therefore, to be two species of pitchstone, the one associated with basaltic, the other with felspathic traps, but the rock commonly so denominated appears to be allied to the latter.

The above-mentioned rocks are found in two different conditions, distinguished by the presence or absence of cells and cavities; the former may be denominated compact, the latter vesicular; terms, which include the corresponding states in which modern volcanic products also occur. Vesicular traps, however, are almost invariably found with their cavities more or less completely filled up with various crystalline minerals, especially calcareous spar, quartz, the several members of the zeolite family, green earth, &c.; hence they are denominated amygdaloids, a term which, in some Geological Treatises, is used to designate a distinct rock, but which in reality constitutes only a particular state, in which all the rocks of the trap family are occasionally found.

Thus we have, amygdaloidal basalt, amygdaloidal greenstone, amygdaloidal wacke, and, though more rarely, amygdaloidal porphyries.

They are also found in fragments or rolled masses, imbedded in a basis consisting of the earthy variety of basaltic or felspathic trap; in other words, either in wacke or in claystone. These mechanical aggregates are known under the generic name of tuff, being called trap-tuff, when the basis is of wacke, and claystone-tuff when it consists of claystone.

Both of them bear a close analogy to the volcanic tuffs, but differ generally in the degree of their aggregation from the latter, the basis of which, being for the most part a kind of volcanic sand, possesses a looser degree of consistency than that which accompanies trap rocks.

*General Characters of the foregoing Rocks.*

The above rocks have this peculiarity belonging to them, that they occur in connection with all the formations enumerated in the former part of this Treatise, from the oldest to the most modern, resting on them in irregular tabular masses, occasionally alternating with, and still more commonly intersecting them at various angles.

When circumstanced in either of the two former ways with reference to the accompanying strata, they have been denominated beds, with what propriety will afterwards appear; when disposed in the latter way they are called trap veins or whin dykes; whin being a provincial term, originally employed by the colliers in Northumberland to designate any hard stone, but now introduced into the general language of Geology, for the purpose of indicating a rock, consisting of basalt, greenstone, or wacke, traversing the strata in the manner that has been represented.

We shall consider, in the first place, the general structure of trap rocks, and afterwards, those circumstances which may be regarded as peculiar, either to the one, or other of the forms in which it is found.

Trap rocks, in some one of their different forms, present examples probably of every kind of structure which has elsewhere been observed: examined on the small scale, we remark them amygdaloidal, porphyritic, and granular; examined on the large, we find them in some instances silty or fine, as clinkstone, in others

divided into thick tabular masses, as basalt and greenstone frequently are.

#### *Prismatic Structure.*

But that which peculiarly distinguishes rocks of the trap family, is the tendency to split into prismatic, or, speaking more generally, polyedral masses, which, though it exists likewise in granitic and a few other species of rocks, is nowhere so frequent or so well displayed as in these. The columns vary in the number of their sides from three, to six, seven, and even twelve; they are more generally straight, but not unfrequently curved; in size they may be said to vary, from an inch to nine feet in breadth, and from a foot to 300 or more in height. They are sometimes continuous for a considerable space, but, at other times are obliquely and irregularly divided by fissures or joints, the convex surface of the one being inserted into a corresponding concavity of the other.

The columns are usually at right angles to the direction of the bed, but not always so; in some instances, indeed, they radiate from a central point, forming clusters of columns without any determinate direction, and still more commonly they are placed so irregularly as to interfere one with the other. Sometimes in the same bed, one portion will be prismatic and the rest amorphous, whilst every intermediate condition, from that of jointed columns possessing an almost architectural regularity, to a total absence of all arrangement, will be perceived.

It has been usual to refer this kind of structure to the contraction, which the mass underwent during its cooling down from a melted state; and there is no doubt, that a prismatic structure may arise from a cause of this kind, as we see exemplified in many modern lavas, and in the shrinking of masses of clay, starch, &c.

But there is one circumstance which seems to prove, that the prismatic form of trap is owing to a different cause; namely, that in many cases the columns approximate so nearly, that not even the blade of a knife can be thrust in between them. Now in every instance in which the same kind of structure is produced by contraction, theory suggests, and experience confirms, the conclusion, that a certain interval would be left between the columnar masses so produced.

#### *Spheroidal Structure.*

We must, therefore, look to some other cause for the columnar arrangement of trap, and probably the true solution will be afforded us, by considering another kind of structure noticed as existing in these rocks, namely, the spheroidal or globular. In this kind of structure, the rock is either wholly or in part arranged in balls of various magnitudes. The globular form is very conspicuous in the rock of the Shiant Islands; but according to Dr. Macculloch does not appear to be common. A tendency, however, to this structure is manifested in most trap rocks, by the manner in which they disintegrate, those even which are columnar exfoliating into spheroidal forms when exposed to the weather. Now, it is evident, that a series of globular concretions of trap, placed in close contact, whilst in a pasty condition, or in the state of transition from fusion to solidity, would be by mutual pressure converted into a succession of jointed columns, which, owing to slight differences in the compactness and consequent softness of the several parts of the mass, would rarely be exact in their sizes and in the number of their sides, but would exhibit all those variations which, in this respect, columnar basalt commonly displays. Neither does it follow, that

they may not in some cases have shrunk, after the prismatic form has been communicated to them by mutual compression, since this would begin to operate from the moment they ceased to be liquid; whereas the tendency to contract would continue up to the time at which the rock had sunk to the temperature of the bodies surrounding it.

We conceive, therefore, that the spheroidal structure will be found to be the one most prevalent in rocks of the trap family, and that the prismatic is in general only a consequence of it; the former, indeed, arising from a kind of molecular attraction, which begins to display itself in all melted bodies, from the moment they cease to be absolutely fluid, up to the time at which they become completely solid. Hence, the longer the interval between these two points, the more fully does this disposition operate, as has been shown by Mr. Gregory Watt and others, who have caused the particles of glass, and even of lava, to arrange themselves in spheroidal concretions, by allowing them, after being melted, to return to a state of solidity with sufficient slowness.

Having now considered the general structure of trap rocks, let us next examine the peculiarities belonging to either of the two conditions in which they exist.

#### *Tabular Masses of Trap.*

One of the most common forms in which the harder varieties of trap are found, is in large overlying masses, sometimes rising into high mountains, but more generally capping the summits of hills of comparatively low elevation. These latter sometimes would seem to indicate stratification, but this appearance is owing to their division into large tabular masses, which again have a tendency to decompose, in an abrupt manner, at right angles to the seams of the stratification, thus presenting a series of mural precipices, ranging one above the other, from which the term trap, which, in Swedish, signifies a *stair*, has been applied to them.

In other cases they appear to alternate with the rocks of the country, but this appearance is most frequently, though not always, deceptive. Dr. Macculloch has shown, that many veins of trap put on a form so far parallel to the stratification, as, when partially viewed, to possess the semblance of beds. Their true nature may in these cases be determined by finding that the parallelism is not long maintained, but that any one such supposed stratum quits its place to intersect the adjoining and including stratified rock, or sends ramifications through the whole series. (See plate v. fig. 6.)

In a few cases, where deep sections of cliffs afford opportunities for examination, it is found, that irregular masses lie beneath the stratified rocks in some places, just as they surmount them in others; and that, from these also, veins proceed to the surface, or in other directions.

Without, therefore, altogether denying, that alternations of trap rocks with neptunian deposits may occur, a consequence which would necessarily ensue, if successive formations of the former rock had taken place at the bottom of water, which was at the time in the act of producing deposits of clay, limestone, or sand; let us go on to consider the case of veins or dykes, to which class the great majority probably of stratiform masses of trap actually belong.

#### *Dykes of Trap.*

These dykes occur of all sizes, from a few inches to twenty or thirty yards in thickness. They extend in

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some cases many miles in length, as in the case of the great Cleaveland dyke in the North of England, which has been traced in a direct line more than seventy miles. They seldom ramify, but pursue their primary direction in one continuous line. They are usually intersected by fissures at right angles to their walls, and are thus divided into irregularly prismatic concretions.

They often penetrate rocks belonging to different epochs, and wherever the circumstances of the country allow us to follow them for any distance, have been found connected with some great mass of the same material. From their superior hardness and durability, they generally resist decomposition better than the rocks which they intersect, and consequently stand out above the surface of the ground, like walls of stone, whence, indeed, they are termed dykes: the term wall and dyke being synonymous in North Britain. Their effects upon the contiguous rocks are very remarkable. The latter are often thrown down on one side, and elevated on the other, as if by the forcible intrusion of the trap. The same thing occurs, when two trap dykes cross one another, that which has been shifted being considered as of the greatest antiquity. The contiguous rock is variously altered according to its mineral constitution. If it be limestone, it is often rendered hard and crystalline, like marble; if shale or slate clay, it is turned into a substance resembling flinty slate or porcelain jasper; if sandstone, it is rendered hard, and, in a few cases, prismatic; if it be gneiss, it is converted into a kind of hornstone. (Nigg near Aberdeen.)

But the most striking alteration is observed, where the dyke intersects the coal strata. In some cases (Cleaveland) the substance of the coal in immediate contact with the trap is converted into soot, whilst at a little distance it is reduced to a coke or cinder, wholly destitute of bitumen. The roof immediately over the coal is lined with crystals of sulphur, which may have been sublimed from the coal.

Nevertheless these effects do not appear to be universal, and it sometimes happens, that a dyke will traverse a series of rocks for a vast distance, without in the least affecting them. They are also much more commonly produced by dykes, than by overlying masses of trap, though the case of the Meisner shows, that a similar influence is sometimes exerted even by a bed of greenstone overlying coal.

#### *Origin of Trap Rocks.*

Such then are the principal facts that seem agreed upon, with respect to the composition, structure, and position of trap rocks; and the conclusion, to which the greater part of them evidently point, is, that they have been produced by igneous action of a kind similar to that, by which volcanic products are forming at the present day.

Their chemical constitution can hardly be held consistent with any other supposition, for they have been found by Kennedy to agree very nearly in this respect with those volcanic products, which they most resemble mineralogically, consisting, like the latter, of compounds of silica, with alumine, lime, and an alkali, commonly potass; substances, which have been never known to enter into chemical union, except under the influence of a high temperature, and have not yet been found as parts of any neptunian deposit, except as rolled masses derived from another quarter.

The general correspondence in mineralogical character,

which may be traced betwixt trap and volcanic rocks, is still more conclusive. Thus the basalts of the one find their analogues amongst the augitic lavas of the other; the syenites and greenstones correspond with the grey-stones or tephrites, and the claystone and felspar porphyry with the trachytes that accompany modern volcanos. We even discover occasionally, in the midst of the products of volcanos, that have been in action since the valleys of the country were excavated, and, therefore, at a recent period, rocks so nearly identical in characters to those which usually are considered as trap, that we cannot deny that the latter are, in fact, produced by volcanic processes. Of this kind are the basaltic colonnades, which occupy the bottom of the valleys in the Vivafais, and have evidently been derived from the volcanic craters above them. The mineralogical and chemical composition, as well as the prismatic structure, of these basalts, are precisely the same as those met with in trap districts; the only distinction that can be perceived being, the presence of void cells or cavities of very minute size, which seldom exist in the older traps without being occupied more or less with crystalline matter.

Neither would it be difficult to find, among the trachytes of Hungary, Auvergne, or the Euganean hills, rocks identical in structure and composition with the porphyries of older date; as, for example, those which accompany the trap rocks at Sandy Brae, in the County of Antrim. The inferences too which an examination of the rocks, placed as it were at the opposite extremities of the series in point of antiquity, could not fail to suggest, are greatly confirmed, by observing the appearances presented by those which belong to an intermediate age. From whatever cause it may have arisen, it is at least certain, that, connected with the deposits belonging to the tertiary periods, is found a class of rocks, which, if regarded as volcanic, seem often to present the characters of trap; and if considered as trap, to put on frequently the characters of recent volcanic products. Such are the formations in the Val di Noto, in Sicily, in several parts of Italy, in Auvergne, in Hungary, and in other parts of Europe, all of which have been traced to one particular period in the history of our Planet; namely, one subsequent to that at which the chalk appears to have been deposited, but antecedent to that in which the Earth was peopled by its present inhabitants.

Nothing, it is clear, could afford a more striking proof of an identity in the origin of trap and volcanic rocks, than this apparent transition from one to the other, in proportion as the circumstances under which they were formed came more and more to resemble those of the present time.

#### *Wernerian Theory with regard to Trap.*

Yet, notwithstanding this accumulation of evidence in favour of the community of their origin, it is no long time since the opposite opinion was espoused by some of the most distinguished Geologists in Europe, and a theory, at once clumsy and gratuitous, was invented, for the purpose of explaining, without having recourse to igneous agency, the position occupied by trap rocks, which lie incumbent on whatever stratum might chance to be uppermost.

No doubt, the weight attached to the name of Werner, who was regarded not unjustly as the father of scientific Geology, gave to his views on this subject a currency, which they would not otherwise have obtained, but even his authority would not have induced his disciples so

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generally to adopt his opinion, had there not been difficulties in the way of the opposite doctrine, which served in some degree as a set-off to the glaring absurdities of their own. We ought indeed, in candour, to suppose, that the Neptunians, as they were called, agreed only in rejecting the volcanic theory of trap as supported by insufficient evidence, and that the majority of them entertained no very decided views with regard to the manner in which it was really formed. Werner, indeed, had called up the ocean to the very summits of the hills, at a period subsequent to the deposition of the other rocks, in order to overspread the Earth with the materials of his newest flötz trap formation; but his followers must have regarded this merely in the light of an hypothesis, brought forward in order to show, that other possible modes of accounting for the origin of trap might be imagined, without invoking the aid of the God of Fire.

We shall not, therefore, concern ourselves with this hypothesis, to which few probably ever attached implicit confidence, but will merely consider, what was the nature of those difficulties, that induced so respectable a class of Geologists, not very long ago, to withhold their assent from the position, that trap rocks were the volcanic products of an earlier period? In doing this, we shall particularly refer to one only of these rocks, namely, to basalt, conceiving the whole question, as to the formation of other members of the series, to hinge entirely upon the result of our inquiry with respect to this.

#### *Arguments in favour of the Aqueous Origin of Basalt.*

The aqueous origin of basalt was asserted, or rather, to speak more correctly, its igneous origin was denied, partly from its relations to other rocks, and partly from its own composition, structure, and position.

It was shown to pass, on the one hand into greenstone, and on the other into wacke, both which substances, it was argued, must have been of aqueous origin: greenstone, because, if it had undergone fusion, the crystals found in it would have been obliterated; wacke, on account of its passage into clay and similar confessedly neptunian deposits.

It was also found to alternate repeatedly with these latter, often without effecting any apparent change in their nature.

The composition of basalt, it was said, contradicts the idea of its having been affected by fire; it contains water, which does not exist, as had been shown by Kennedy, in the recent lavas most nearly allied to it—it contains various crystals which are fusible at a heat below that at which basalt melts—and it even envelopes masses of limestone, containing all their carbonic acid, and occasionally with their petrifactions uninjured. The structure of basalt is, it was alleged, still more strongly opposed to such an opinion; instead of being vesicular, marsh, and vitreous, like modern lavas, it was compact, stony, and sonorous like iron; instead of being split into irregular, polyedral masses, with wide, intervening spaces, it was often divided into prisms affecting a great degree of regularity, and closely touching each other.

Unlike lavas, it cannot be traced to a crater; nor does it, like them, descend into the bottoms of valleys; but is found often capping hills, whilst it is entirely absent from the low country contiguous.

As to the similarity between basalts and lavas in point of chemical composition, it was argued, that this only

proved the latter to have been derived from the fusion of trap, not the former to have been produced by heat themselves.

#### *Shown to be fallacious.*

Some of these arguments, no doubt, were founded on a mistaken representation of facts: thus wacke being an earthy kind of trap, and containing the same ingredients as basalt, may be produced in some instances from the disintegration of the latter rock; and when that is the case, its further decomposition would give rise to a rock no wise different from clay. All the cases, probably, in which the passage from basalt to clay has been asserted, fall under this predicament.

The greater number, too, of the cases cited, in which organic remains are said to have been detected in trap, are equally erroneous: the rock in which they are found, being either a trap tuff, as in the Island of Canina; or a wacke, derived, probably, from the decomposition of basalt, as at Joachimstal, in Saxony; or, lastly, a rock altered by the contact of basalt, as the flinty slate of Portrush, near the Giant's Causeway, which contains ammonites.

But, even if basalt had in any instance been found to contain organic remains, this would be no more than has been met with among the ejections of volcanoes. Thus, as Mr. Delabèche informs us, in Signor Monticelli's collection of Vesuvian products at Naples, occur fragments of the compact limestones of the district with their organic remains imbedded.

The presence of crystals fusible at a heat below that required by their matrix, offers no objection to the igneous origin of trap, now that it is conceded, that these very crystals may have been produced subsequently, owing to the play of affinities brought about by the fusion of the mass, and operating during the progress of its return to a state of solidity.

#### *Differences between Lava and Basalt explained.*

But there are other manifest differences between basalts and lavas, which require to be accounted for, before we allow ourselves to refer the former to volcanic agency; namely, their greater compactness and more stony aspect, the general absence of glassy and of vesicular products, the more regular prismatic structure which they assume, their originating in dykes, and not in craters, and other peculiarities above alluded to.

It remains then to be seen, what were the conditions, which caused the volcanic products of an earlier period to assume an appearance in many respects so different from that which they affect at present.

One circumstance will immediately occur to us, as establishing a distinction between the two cases.

We have seen in the former part of this Treatise, that up to the period of the tertiary formations, the greater part of the Globe, or at least of that portion of it which has come under our observation, was covered to a great depth by water; for, although the formation of beds of coal, the occasional occurrence of fresh-water shells, and that of the remains of land animals, convince us, that certain portions of what is now dry land was even at that time elevated above the waters: still it is probable, that these constituted merely detached Islands in the midst of the abyss of ocean; and that the great bulk of our continents were at that period submerged. It follows from this, that the majority of



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the trap rocks then formed must have been submarine lavas, and hence we see at once a distinction between the above and those of the present day, which, wherever they are presented to our observation, are necessarily subaereal, or at least consolidated only in shallow water. Thus in the volcanic Island recently produced in the Mediterranean, the products that have come under our notice, are porous and vitreous, like those of Vesuvius; but these, though products of a submarine volcano, have all been ejected into the open air, and, consequently, partake of the character of subaereal lavas.

#### *Effects of Heat modified by Pressure.*

This distinction, first pointed out by Dolomieu and Strange, was happily applied by Dr. Hutton, in his celebrated Theory of the Earth, to account for the differences between trap rocks and lavas, on the principle, that the effect of the heat applied would be modified in these two cases, by the influence of the pressure exercised by a superincumbent ocean upon the former, and by the absence of any such pressure on the latter.

"The tendency of an increased pressure," to use the words of his illustrator, Professor Playfair, "on the bodies to which heat was applied, is to restrain the volatility of those parts which otherwise would make their escape, and to force them to endure a more intense action of heat. At a certain depth under the sea, therefore, the power of a very intense heat might be unable to drive off the oily or bituminous parts from the inflammable matter there deposited; so that, when the heat was withdrawn, these principles might be found still united to the earthy and carbonic parts, forming a substance very unlike the residuum obtained after combustion under a pressure no greater than that of the atmosphere. It is in like manner reasonable to believe, that on the application of heat to calcareous bodies under great compression, the carbonic acid would be forced to remain, the generation of quicklime would be prevented, and the whole might be softened, or even completely melted; which last effect, though not deducible from any experiment yet made, is rendered very possible from the analogy of certain phenomena."

These latter anticipations were soon after realized by the masterly experiments undertaken by Sir James Hall, which showed, that the carbonic acid, usually driven off from limestone by the action of heat, may be retained in combination with it by a pressure greatly inferior to that of the present ocean; and that the calcareous matter under such circumstances enters into fusion at a temperature, which it completely resists when this elastic material is expelled.

Sir James Hall has applied this discovery with great success to the explanation of the calcareous matter occurring in the cavities of amygdaloidal traps, and the water present in those of certain agates existing in the same class of rocks. The same will also account for the greater cellularity which modern lavas possess than the generality of traps, the former, even in the innermost part of the stream, where, owing to the pressure of the superincumbent mass, their density will be greatest, exhibiting a number of minute vesicles, the existence of which serves to distinguish them from ordinary basalt.

Not that we must suppose all trap rocks to be destitute of cells, any more than we are warranted in inferring, that all the eruptions that took place at these periods necessarily occurred in deep water.

The existence of amygdaloids, such as are the toad-stones of Derbyshire, seems to imply, that the pressure under which certain traps were formed was not sufficient to prevent the disengagement of aeriform fluids; for it is difficult to reconcile this phenomenon to the theory of Sir James Hall, who imagined that such cavities were caused by the infiltration of the crystalline matter, which, when it entered into fusion with the whinstone, kept separate from it, as oil does from water. If this had been the cause of the cavities, they ought to be entirely filled with crystalline matter, which is not the case. Neither is the presence of crystalline matter occupying the cavities a fact absolutely without exceptions. Dr. Macculloch instances the trap of Little Cumbray, in the Kyles of Bute, as consisting of vesicular lava, so light as almost to float on water, having its cells entirely empty, and with a glazed, internal surface, like that of volcanic scorice.

But these partial exceptions will not be considered as sufficient to invalidate the general position, that traps are of submarine origin, until some Geologist will either undertake to explain, on some other principle, the differences allowed to subsist between them and lavas, or will point out the inadequacy of Sir James Hall's theory to account for these points of distinction.

#### *Why submarine Lavas cool slowly.*

It is true, that the stony aspect of basalt, and the crystalline or granular appearance belonging to greenstone and other members of the trap formation, are less obvious consequences of the principle therein assumed. But it will not be difficult to show, that, although a body of shallow water, from the more rapid cooling it would occasion, was likely to favour the formation of vitreous products even more remarkably, than that exposure to the atmosphere which subaereal lavas undergo; yet deep water would possess the opposite tendency so completely, that we ought to meet among submarine lavas few substances of this description, except where the material had been injected in thin streams into the fissures of a rock, possessing a different temperature, and therefore capable of robbing it of its heat in a more rapid manner.

In order to understand this, we need only recollect, that the cooling agency of water under ordinary circumstances, is owing, not to its being a good conductor of caloric, but to the circulation induced in the strata of that fluid when heat is applied to it.

This circulation is effected in two ways: in some degree, by the heated particles of water at bottom becoming specifically lighter, and consequently displacing those above, but in a still greater degree, owing to the absorption and subsequent disengagement of caloric, caused by the conversion of successive portions of water into steam, and their return to their original condition, when they come into contact with the supernatant liquor.

Now it seems almost a corollary from the laws established by Sir James Hall, and others, that at the bottom of the ocean none of the water could be converted into steam; for if, as this writer infers, the pressure was sufficient to preserve water existing in the very midst of the lava (where the heat must be supposed to be at its maximum) in a liquid form, still more completely would it prevent that, which was incumbent on the heated mass, from assuming a gaseous condition in consequence

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of the heat communicated from below. It seems probable, therefore, that, as water is in itself a slow conductor of heat, the cooling of submarine lavas ought to proceed still more leisurely than that of subaereal ones is found to do, and hence that their component parts would remain for a still longer time in that intermediate condition between fluidity and solidity, during which, as Mr. Gregory Watt and others have satisfactorily shown, the particles, released from the controlling power of cohesive attraction, and yet brought within distances favourable to the play of their mutual affinities, enter most readily into new combinations, and assume those crystalline arrangements which are natural to them.

Perhaps, likewise, the superior density of submarine lavas, the general absence of cells, and their not sending forth to the same extent those emanations of gaseous matter which appear to proceed from modern currents, might contribute to the same effect by still further prolonging the period of cooling.

#### *Prismatic Structure accounted for.*

The same considerations may explain the prismatic structure belonging to many traps, which we have shown to have resulted from the tendency to form spheroidal concretions, naturally assumed by such rocks on being allowed to cool slowly. Instances of this same structure are stated to occur amongst modern volcanic formations; as by Mr. Scrope, in the interior of the crater of Vesuvius, as displayed in 1822; and by Breislac and others, in the lower portions of a lava bed at Torre del Greco. It is certain, however, that such cases are rare, and that those igneous rocks of recent origin, in which an approach to such a structure is observable, appear for the most part to have derived it rather from the contraction occasioned by sudden cooling, than from the mutual pressure of spheroidal concretions taking place during a more gradual one.

Such are the columns of lava worked into millstones at Niedermennig, near Andernach, which manifest their real origin by gradually approximating more and more, until at a certain depth they become united into one continuous mass. Such also are the rude columns observed near Torre del Greco, belonging to a bed of lava that had flowed into the sea, the result evidently of the rapid cooling thereby occasioned; and in another instance from the same locality, in which, as Professor Lyell observes, "the rock may rather be said to be divided into numerous perpendicular fissures, than to be prismatic, although the same picturesque effect is produced. In the lava currents of Central France, (those of the Vivarais in particular,) the uppermost portion, often forty feet or more in thickness, is an amorphous mass passing downwards into lava, irregularly prismatic; and under this, there is a foundation of regular and vertical columns, in that part of the current which must have cooled most slowly. But the lavas last mentioned are often one hundred feet or more in thickness, and we cannot expect to discover the same phenomenon in the shallow currents of Vesuvius, although it may be looked for in modern streams in Iceland, which exceed even those of ancient France in volume."

Now the greater frequency of prismatic rocks in submarine than in subaereal volcanos is explained, by reflecting, that the slow cooling essential to that structure, which in the latter is accidentally; or in a few cases, brought about by the remarkable thickness of the mass

superincumbent, and that only in the lower portions of the bed, is caused in the former throughout, by the vast pressure of the ocean above, whatever may be the supposed thickness of the bed itself.

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#### *Greater frequency of Dykes.*

With regard to the next point to be considered, namely, the absence of craters, and the greater frequency of dykes in trap rocks, it must be admitted, that we are rather unfavourably circumstanced in order to draw a correct comparison between these and more recent volcanic products in the latter particulars. The craters of submarine volcanos, when composed of loose fragments, would be exactly the portions most likely to have been swept away by the currents of the ocean, or other causes; whilst if they consisted of lavas, they might indeed remain, and yet all vestiges of their original configuration be obliterated by the rocks superimposed.

It would be rash therefore to assert, that craters never have existed, because we do not discover any traces of them at present. On the other hand, it is only where accidental circumstances reveal to us the internal structure of a modern volcano, that we can expect to find dykes, and there we do occasionally meet with them. Thus they are well known to exist on the sides of the old crater of Monte Somma, (see pl. v. fig. 5.) and Professor Lyell has noticed the same in that of Vesuvius at present; these, however, are probably produced by the filling up of open fissures with liquid lava, which had occupied the hollow of the crater, and therefore do not precisely resemble in the mode of their formation those trap dykes which exist in older rocks, the results of an injection of liquid lava into the fissures, through which it made its escape to the surface.

In order fairly to compare together the action of ancient and modern volcanos in this respect, we ought to refer to sections of some modern volcanic mountain, taken at a distance from its crater, of which some of the Lipari Islands afford us good examples, (see Daubeny's *Descriptions of Volcanos*, and pl. v. fig. 1 and 2,) as also does the Val de Bove in Etna, described by Professor Lyell. (See pl. v. fig. 3 and 4.)

There we shall see dykes, which, though mineralogically resembling modern lavas, correspond, in their relation to the contiguous rocks, to the trap dykes described by Dr. Macculloch in his *Western Islands*, as running for a considerable space parallel to the strata, though originating in some great mass of trap underneath. (See pl. v. fig. 6.)

Nevertheless, although it is impossible by a direct appeal to facts to establish beyond the reach of cavil the greater frequency of dykes amongst submarine volcanos, yet probability is certainly in favour of such an assumption.

"If volcanic forces," remarks Professor Sedgwick, "ever have acted on a great scale upon unbroken and nearly horizontal strata, especially while such strata were under the pressure of the sea, the formation of tabular and vertical masses of lava appears a natural consequence of such action. Where, on the contrary, the pressure of the sea is removed, and the crust of the earth is broken through, volcanic fluids will find a ready escape, eruptions of lava will be confined to one spot, and the operations will be of a class altogether different." (Sedgwick's *Geol. of High Teesdale*.)



*Trap Rocks, at what Periods formed.*

The admission, that trap rocks are lavas, tends very much to enlarge our ideas with respect to the extent of volcanic action at different periods.

From the occurrence of these products in connection with every secondary formation, from the earliest down to the most recent, the chalk, it might be concluded, that volcanic action had taken place during every one of these successive periods; but, except when they can be proved to stand in the relation of beds interposed between the strata, such an inference would not be warranted.

Let us take, for example, the oldest rock with which any considerable mass of trap is associated in Great Britain, namely, the carboniferous system of the Northern Counties, and that in the neighbourhood of Glasgow and Edinburgh.

The former of these, namely the coal field of Northumberland, is associated with many very remarkable dykes, overlying masses, and apparent beds of trap, but the most considerable of the latter, the great whin-sill, which is seen arranged conformably with the carboniferous limestone of Teesdale, and the Northern lixestones of Northumberland, has been pronounced by Professor Sedgwick to be in fact a stupendous dyke, or collection of dykes, which has been injected laterally between the strata. He, however, is inclined to refer the injection of this, as well as of the majority of the trap rocks of that neighbourhood, to a period antecedent to the magnesian limestone. Mr. Hutton, and Mr. Phillips of York, differ from the professor in their view of the origin of the whin-sill, regarding it as in great measure formed by periodical submarine eruptions of lava, which took place at intervals during the deposition of the carboniferous strata with which it is associated. In either case, therefore, much of this extensive basaltic formation is allowed to be of a date as ancient as the carboniferous rocks themselves.

The trap rocks of Staffordshire, on the contrary, constitute overlying masses, which may either be contemporaneous with the coal measures on which they rest, or may have been of a date much posterior.

Lastly, the trap rocks near Glasgow are so connected with those of the Western Islands, as the latter again are with those of the County of Antrim, which are posterior to the chalk, that we should be led to assign a much later epoch to their ejection, and likewise, perhaps, to extend the same inference to those in the vicinity of Edinburgh.

Thus we have three cases brought together, in which trap rocks are associated with the same system of rocks; the one of which is of a date antecedent to the magnesian limestone, or at latest contemporaneous with it, the third of the same age as the chalk, and the second doubtful.

In Derbyshire we meet with an apparent alternation of beds of trap called toadstone, which are more generally amygdaloidal, but occasionally compact, with the carboniferous limestone formation. But before we absolutely decided that the two are contemporaneous, it would be necessary to establish more completely than has yet been done, that they are conformable. If this be not the case, they may have been ejected long subsequently.

The most extensive, however, and in all respects the most interesting system of trap rocks, found within the compass of the United Kingdom, is that which

occurs in the Western Islands of Scotland, and which appears to be continued on in the County of Antrim, in Ireland. It is interesting, not only from the numerous sections which its situation near the coast supplies, but likewise from the circumstance, that it is not mixed up, as those in other instances are, with the volcanic rocks of an intermediate period, no remnant of the operations which occasioned it being discoverable, either by the existence of hot springs, emanations of carbonic acid, or even earthquakes of any remarkable kind in the contiguous country.

It affords us, therefore, the means of comparing the products of submarine volcanos with those of subaereal ones, and at the same time of inferring, on evidence as conclusive, perhaps, as the subject itself can ever admit of being adduced, that volcanic action has in some instances expended itself, or at least has periods of rest beyond comparison longer in some cases than in others. Now either of these suppositions seems more consistent with the chemical theory, which imagines a definite quantity of combustible materials to be present in particular situations, than with the opposite one, which conceives the existence of an unexhausted fountain of melted matter underneath, such as should either gush out continually, or at least flow at intervals more approaching to regularity.

The trap rocks of the Hebrides manifest themselves under all the forms which have before been alluded to; but it would seem from the observations of Macculloch and others, that the apparent alternations which have been remarked between them and the rocks of the country, are merely caused by dykes intruded laterally between the fissures of the strata. Hence we are only sure, that a considerable part at least of these trap rocks is posterior to the most recent of the strata found associated with them, and the latter appear from the researches of Mr. Murchison to belong to the oolitic series.

But there is no evidence, that they may not be much later; for the basalts of the Giant's Causeway, on the opposite coast of Ireland, intersect the chalk, and are, therefore, posterior to that formation.

It is true, that Dr. Macculloch has shown, from the occurrence of trap nodules in a conglomerate rock of Kerrera, that trap rocks must have been formed at a much earlier period; (*Western Islands*, vol. i. p. 114;) but, as we cannot on any supposition refer the whole to this epoch, we are quite at liberty to adopt any inferences, to which the facts may appear to lead, with respect to the age of the principal portion of that found in the Hebrides.

Perhaps, therefore, the Wernerians were not altogether wrong, in referring the great overlying masses of trap, that they observed in Saxony and elsewhere, to one epoch, and that the most recent, which, in the then existing state of their ignorance with respect to tertiary rocks, they were able to recognise, designating them by the name of the newest flatz trap formation; for although we may be compelled to acknowledge, that these rocks are of several distinct periods, and that in a great majority of cases their date is uncertain, still it seems by no means improbable, that the most extensive eruptions of submarine volcanos took place about the period just alluded to.

This is rendered more agreeable to analogy, when we remark, that by far the most extensive manifestations of volcanic agency appear to have occurred, either at a period contemporaneous with that to which we have supposed the trap rocks to belong, or at one immediately

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subsequent to it, that is, during the deposition of the different tertiary formations.

It is remarkable, at least, that all the extinct, as well as all the active volcanos, which have been as yet explored, may be traced up to this period, regarding, that is, as we have a right to do, all the volcanic rocks of a district as emanating from the same focus of action.

Thus the lavas of the Val di Noto alternate with rocks which appear to be tertiary; as also do those of Auvergne, of Hungary, of Styria, and of the North of Italy; so that, whether we regard the trap rocks of the Hebrides as contemporaneous with the latter, and attribute their greater compactness to the depth of water under which they were ejected, and from which they may have since been upraised, or whether we prefer to consider them as produced somewhat earlier, still we shall find equal reason for concluding, that during the period comprised between the date of the deposition of the chalk, and that of the creation of the existing races of animals, circumstances were peculiarly favourable to the development of volcanic operations.

It is remarkable, too, that trachyte, properly so called, seems almost confined to this intermediate period; for although Humboldt speaks doubtfully as to the position of this rock in the New World, yet in the Old, it is found in a number of instances posterior to some of the tertiary rocks, and we know of no instance in which it is decidedly proved to be of greater antiquity, whilst its rarity amongst lavas of modern ejection would seem to show, that it was not, under ordinary circumstances, a product of existing volcanos. Whether this circumstance is to be regarded as the *cause* or the *effect* of that elevation of a large portion of our continents from the sea, which took place at this epoch, it may be difficult to say; but it is certain, that both events may be traced to nearly the same period; and hence we observe amongst the volcanic rocks of this age, that singular intermixture of compact with cellular, of glassy with lithoid lavas, which, at the same time that it affords the most decisive evidence of the igneous origin of trap, indicates the different circumstances under which these rocks were formed; sometimes under the pressure of water, and at other times elevated above it.

## SECTION 2.

## On Granitic Rocks.

Various  
conditions  
of the pro-  
duction of  
igneous  
rocks.

The circumstances under which the germs of igneous energy may be excited to activity, are so various, that even amongst volcanic products poured into the atmosphere, there is great local diversity. If we remember that, for the most part, the phenomena of submarine volcanic action are wholly concealed from our view, we shall be prepared to expect that among the masses formerly produced by it beneath the bed of the sea, and uplifted by subsequent convulsions to the day, many varieties of rocks should be met with, differing very greatly from the products of actual volcanos. As the far greater portion of volcanic effects takes place in the deep parts of the earth, where the rocks remain to be again and again exposed to new influences, it is reasonable to suppose that the products collected from volcanic vents form but a small part of the series.

The subterranean lavas, now in course of production and consolidation, could they be uplifted to the day, would be found very different from the superficial lavas,

and far more extensive and abundant. Though, as the preceding section has shown, there be many close analogies between ancient and modern igneous rocks, we ought to expect that the most abundant of these old rocks, while they afford sufficient evidence of their being generated by heat, should appear different from ordinary lava. Granitic rocks are exactly in this case; they are far more abundant than the trap rocks, which most closely imitate volcanic products, and have a different general character. Yet as between superficial and subterranean lava every variety of products may be expected to occur, corresponding to the various conditions, we find between granitic and basaltic rocks so many intermediate varieties, that it is impossible to separate by hard and decisive characters these extremes of the series of old igneous rocks. Basalt is really a volcanic product, in the restricted sense of the word, though not exclusively so; and thus we have from vesicular pumice, and glassy obsidian an uninterrupted series of gradually changing aggregations to granite.

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Granite deviates on the one hand by continual decrease of the magnitude of its particles into very close-grained felspathic rocks, which are greatly analogous to certain kinds of porphyry; on the other, by the substitution of hornblende for mica into syenite. As examples of the latter change, we may instance the syenitic granites of Crataean and Strontian: the former is illustrated in the granite veins of Arran, and in the fine grained granite of Wastdale and Dulton Pike. (Westmoreland.) In some cases it might, perhaps, be safely admitted, that the same originally fluid mass has been consolidated partly into granite and partly into porphyry, according to the circumstances in which the lapidification happened. In the Valteline granite deviates into hypersthene rock.

Rocks allied  
to granite.

It would be a mere waste of time to repeat, for the particular case of granite, those arguments, derived from the crystalline aggregation of many minerals never known to be produced from water, but several of which have been fabricated in the furnace, and nearly all are volcanic products, which establish the probability of the igneous origin of the whole class of plutonic rocks. We have shown above that the composition of granite passes by very easy steps to that of rocks whose igneous origin is perfectly unquestionable; if to this we add the fact, of granite entering cracks and fissures in contiguous rocks, as clay slate in Cornwall, hornblende slate in Glen Tilt, gneiss in Cumberland and at Strontian, we shall have said enough in the present advanced state of Geology to secure the admission that granite was generated by heat.

General  
argument.

The alternations which in several Countries obtain between granite and some of the older stratified rocks, as mica-schist, gneiss, &c., seem not at all irreconcilable with this view; but they will hereafter, when rightly understood, be found of great value in determining some peculiar conditions of the granitic eruptions.

If we seek to understand the circumstances which have impressed upon granite characters so generally distinct from those of the other plutonic rocks, we shall find the following facts important. 1. Granitic rocks usually occur in very large masses below the whole, or a very large part of the whole series of strata, and were evidently formed under the pressure of a great body of water, if not under a pile of superincumbent strata. 2. They are so extensively spread beneath the neptunian rocks as to deserve, perhaps more than any other, the title of an universal formation. 3. Granite veins, in

Peculiar  
character of  
granite.

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proportion to their minuteness and distance from the parent mass, grow continually finer in the grain and more porphyroidal in every respect. This effect is most completely seen along the sides of the veins. 4. In Countries where the great masses of igneous rocks are granitic, as for example Cumberland, the dykes and smaller masses are mostly of porphyry, or of a felspathic quartzose rock, of rather dubious character, which may be called syenite, porphyry, or unmicaceous granite, according to the locality. Such rocks occur about Wasdale head, in St. John's Vale, under Helvellyn, and in High Pike.

On comparing these general facts with Mr. G. Watt's experiments on the aggregation of fused basalt, there appears sufficient ground for believing that the very high crystalline character of granite is owing to its being produced at great depths where it was very slowly cooled to the point of crystallization. We may further venture the hypothesis, that porphyry is merely another state of consolidation of a similar felspathic compound, as trachyte has been supposed to be derived from older porphyries, or even from granite.

Comparison of ancient and modern pyrogenous rocks.

It appears, therefore, that among the older pyrogenous rocks we may distinguish the same two leading groups as among the modern volcanic products, characterised by the prevalence of some kind of felspar in the first, and of augite, hornblende, hypersthene, diallage, or some other analogous generally ferruginous mineral in the second; that in each of these occurs a great variety in the size, distinctness, and aggregation of the crystals, corresponding to the circumstances of the consolidation and differences of composition of the mass. The following short synopsis will express some of these relations among the older rocks.

Plutonic rocks are—1. Felspathic, as granite, porphyritic granite, porphyry, amygdaloidal porphyry, claystone, pitchstone.

2. Hornblende, hypersthene, &c. { Felspathic, as syenite, hypersthene rock, gabbro, serpentine.

3. Hornblende, hypersthene, &c. { As greenstone, basalt, trap porphyry, melaphyre, amygdaloidal traps, wacke.

On reviewing this series, and considering the manner of occurrence of the several members of it, we shall find that the prismatic structure is perhaps more generally developed in the augitic and hornblende pyrogenous rocks, than in the felspathic branch, and that in both groups the highly crystallized varieties, as granite, syenite, and greenstone, exhibit less of this character than is common to granular claystone and glassy pitchstone, or fine grained basalt and trap porphyry.

Granite veins.

Another thing worthy of notice, is the circumstance that veins proceeding from the mass of a pyrogenous rock into the small cracks and short fissures of a stratified rock are almost peculiar to granite. This phenomenon is hardly ever noticed along the sides of a dyke or interposed bed of basalt or porphyry, and is at least very uncommon in connection with even large masses of greenstone. On the contrary, granite is very seldom found in dykes like the augitic and hornblende rocks, though there is reason to believe that it assumes the form of overlying masses, and alternates in seeming beds with gneiss or mica slate. (S. E. of Ireland, p. 563.)

The variety of interesting considerations connected

with granite will justify us in taking a more extended review of its mineral and chemical composition than were necessary while treating of other pyrogenous rocks. Granitic rocks have long been regarded as the source of most of the ingredients of sedimentary strata; a newer theory supposes that granitic rocks are continually forming beneath our feet, in quantities proportioned to the time, by the action of subterranean heat upon the hydrogenous strata. Or both of these points some further information concerning the composition of granite will be useful.

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Granite is essentially a felspathic rock. Whatever variations happen in respect of the quantity of other ingredients, felspar, in a crystallized state, is universally the basis of granite. In graphic granite the planes of crystallization of the felspar are continuous for great spaces; in porphyritic granite it generally happens that the axes of the prismatic crystals of felspar lie nearly in the same direction; but in common granites it is probable that the crystals of felspar lie in all directions, like the calcareous crystals of primary limestone. The felspar is red, white, green, &c.

Quartz, in a grey, transparent state, more or less evidently crystallized, is almost never absent from granite, but its quantity is very unequal. In graphic granite, quartz, in a sort of interrupted crystallization, is engaged among the laminae of felspar, so as to assume angular and intersecting figures not unlike the characters of some Oriental language. In the porphyritic granite of Westmoreland the natural faces of the large crystals of felspar are impressed with very small bipyramidal crystals of quartz; and in other granites the quartz may generally, with care, be found crystallized in this form, so as to present on a polished face a regular or elongated hexagonal section. There seems also in some granites a portion of uncrystallized quartz, which is entangled among the other ingredients in irregular shapes. Binary granite, of quartz and felspar only, is seldom met with in Great Britain. It forms part of Muncaster fell in Cumberland.

Mica, the third ordinary ingredient in granite, is occasionally very abundant in it but sometimes absent. It is universally crystallized, generally in regular hexahedral plain laminae, which either or cut into the crystals of felspar and quartz, without being themselves interfered with. The direction of the crystals of mica is indeterminate; they do not occur in continuous laminae, so as to cause the rock to cleave; for though porphyritic granite is in a certain sense cleavable, this arises from the parallelism of the crystalline axes of the felspar. Yet in some Cornish granites we occasionally see the mica aggregated together in a sort of shell, which gives a notion of some kind of lamination, arising perhaps from a limited intestine movement of the mass.

It is generally presumed that the three most common ingredients of granite were crystallized together; by which is meant, that the consolidation of all the crystals was contemporaneous, neither preceding nor following another. This seems not always exactly true. In many cases we cannot doubt that mica was crystallized before the other ingredients. If we follow the indications of the penetration of crystalline forms, we shall find in several instances that the figure of the quartz was complete before the felspar was wholly consolidated; and perhaps, adding to this the consideration that the felspar in the solid parts of granite has, in general, only one, and that the primary form of its crystals, while

Order of crystallization.

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quartz and mica invariably appear in secondary forms, we may venture to conclude that the felspar was the last crystallized, and, by consequence, has imparted to the mass its most important features. In many large grained granites are cavities, in which free crystallizations of the ingredients occur. In these cases the minerals show themselves in much greater variety of forms, especially the quartz and the felspar. The former assumes variously terminated prismatic forms; the latter is in rhomboids variously modified. (Baveno; Arran.)

Contemporaneous  
veins.

The aspect of granite is very often diversified by the occurrence of what are called contemporaneous veins; a term which is meant to convey the assertion that the difference of character which it marks was coeval with the formation of the rock. In the large grained granite of Arran and Cornwall, the contemporaneous veins usually appear as long, narrow, ramifying portions of finer grain and a different proportion of ingredients; sometimes with more mica, sometimes with less. The boundaries of these "veins" are indistinct, and the two structures gradually pass into one another.

It will be readily conceived, that a stone composed of crystals so much independent of each other may, especially when the felspar is not very predominant, be very far from solid; it may be very full of minute fissures. These are often clearly enough perceived, sometimes partially filled with small grains of quartz, steatite, felspar, mica, &c. When the stone is by any means subjected to decomposition, the several crystallized ingredients easily separate along these opening cracks.

Imbedded  
minerals.

It is almost unnecessary to enumerate the various other minerals which are disseminated in granite, except for the purpose of showing how many minerals may be developed from the same fundamental fluid mass. As all of them are definite compounds of certain ingredients, and only one simple earthy substance (quartz) remains as a residuum, it is no wonder they are mostly silicates of earthy substances, and that their relative quantity is very unequal, depending upon the possible atomic combinations which should exactly exhaust all the ingredients except the superfluous quartz.

**Silicates.** Tourmaline, topaz, zircon, cordierite, epidote, garnet, lepidolite, petalite, triphane, steatite, talc, schorl, hypersthene, hornblende, augite.

**Aluminates.** Cymophane, beryl, pinite.

**Sulphuret of bismuth, sulphuret of molybdenum, tungstate of iron, rutile, oxide of tin, graphite, oxide of iron, &c.**

Restricting ourselves to the more common varieties of granite, we may observe, that the difference in the crystallization of the ingredients could not be determined *a priori*, from considerations of the relative fusibility of the minerals; because, in fact, these minerals were all developed from one uniform melted mass, in which the only distinct parts were the elementary substances of silica, alumina, lime, potash, oxide of iron, &c. and it would depend chiefly upon the relative cohesive forces and chemical attractions of certain proportions of these ingredients what crystals should be first generated. In trinary granite, for example, it may not be that mica and quartz were crystallized before felspar because this latter is the more fusible substance, but because out of the mingled mass of elementary substances the particular combination which constitutes mica was endowed with the highest attractive energy. Mica might be formed out of a melted mass at a temperature very far below that required for its own fusion; this being separated,

there would remain a silicated felspar, from which the excess of silica being separated, it might depend upon the state of the mass as to heat, whether both quartz and felspar should crystallize together with mutual penetration, or the former impress the latter.

If we assume granite to consist of 20 parts of felspar, 5 parts of quartz, 2 of mica, the fused glass from which, on cooling, these minerals were crystallized, must have contained about

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composition  
of granite.

Silica ...	1853	} of which {	1353	} formed felspar and mica, leaving a residuum of silica.
Alumina .	404		404	
Potash ...	282		282	
Lime ....	40		40	
Ox. iron ..	44		44	
Ox. mang.	3		3	

Had the proportions of alumina and the metallic oxides been greater, it is probable that more mica would have been formed; had they been less, less mica and more felspar might have resulted; and the proportions of the ingredients might have been such that the mica and felspar might be provided with their constituent potash and other parts, hornblende or augite, or hypersthene, with their lime, magnesia, &c., and a residue of quartz remain.

According to the rate of cooling we might have a large grained or fine grained granite, or a nearly compact rock: if the quantity of felspar was very great, and the cooling rightly proportioned, the mica and quartz might be crystallized in a compact, earthy, or glassy uncrystallized basis. Thus felspar porphyry would be produced from the same ingredients as ordinary granite; and the whole investigation appears to teach us that the mineral characters of pyrogenous rocks depend as much upon the circumstances of their solidification as upon original differences of chemical composition. With this all observations on these rocks fully agree; and it is, therefore, in a right spirit of philosophical generalization that Geologists have now accustomed themselves to view the whole series of plutonic and volcanic products as the varied results of one original mode of calorific action operating under a variety of conditions as to cooling, pressure, limitation of space, and other influential circumstances.

## SECTION 3.

### Relative Age and characteristic Phenomena of Pyrogenous Rocks.

Were our inquiries concerning the relative age of plutonic rocks to be answered only by appeal to observation of the phenomena which they present in contact with one another, the research must be abandoned. For they neither show themselves so often in connection, nor display, when in connection, such marks of relative antiquity as to permit us to recognise more than one general truth, viz. that granite is very often the oldest and basalt very often the youngest of these rocks. But by studying separately the age of each of these rocks in relation to the strata which adjoin it, we obtain a more extensive and more exact series of determinations concerning the periods when they have been erupted through the consolidated crust of the earth. The importance of these determinations in inductive Geology is so great as to demand a preliminary statement of the mode of reasoning employed in obtaining them.

1. When in any Country a certain class of rocks, as for instance the slate rocks, have been convulsed and thrown

Age of plu-  
tonic rocks.

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Ch. III.Age of plu-  
tonic rocks.

into new positions before the deposition of another set upon them, as for instance the carboniferous rocks, and we find occupying the axis or nucleus of the dislocation a mass of granite, it is certain that such granite is older than the carboniferous system because it was uplifted with the older slates. If, in addition, this granite sends veins through the slate rocks so as to prove that it was uplifted in a melted state, we must infer that it is of more recent origin than those slates; and, in fact, that its antiquity is exactly measured by the date of the convulsion.

If there be no veins thrown off from the mass of granite, and no other satisfactory proof of its having been uplifted in a melted state, the age of the igneous rock is indefinable, except by saying that it is older than a given stratified rock. Such a case occurs in the Ord of Caithness. It appears, then, that in any case of convulsion the era of the elevation of the igneous rock is determined by the convulsion, but whether it was actually generated at that time from a melted state, requires other evidence. Now this consolidation from a melted state is what fixes the age of an igneous rock. Granite may, perhaps, have remained melted in the deep parts of the earth through many geological periods, but its age as a rock is counted from the period when its fusion closed.

2. In Derbyshire the carboniferous limestone is inter-laminated for great lengths by an igneous rock, (toad-stone,) which has evidently been poured out at certain intervals by an ancient submarine volcano while the limestone was in formation. The age of such a rock is fixed by the age of the limestone.

3. The basalt of dykes which pass through certain strata, is, of course, not more ancient than the newest strata divided; if at any point the dyke should be covered by newer strata which are undisturbed by the dislocation accompanying it, we may generally admit that the basalt is older than these strata. Such a case, perhaps, occurs in the dykes of the Durham coal field, which do not penetrate the magnesian limestone.

These instances are sufficient to show the truth of two propositions of general application to this subject.

When igneous rocks accompany convulsions, we can always fix the minimum of their geological antiquity; when they throw off veins or intrude in the shape of dykes, or interpolated beds, among stratified rocks, we are able to assign the maximum of their antiquity.

Guided by these views, and restricting our illustrations as much as possible to the British Isles, we may proceed to describe some of the characteristic phenomena occasioned by the appearance of plutonic rocks, and to fix the eras of their production.

First, we shall describe the general features of a district remarkable for the number of these rocks brought into a small compass and presenting diversified effects, and then select instances proper to make known the characters of each.

We shall take an example of the phenomena of pyrogenous rocks in general from that gem of Hutonian Geology the justly celebrated Island of Arran, an examination of which may be safely pronounced almost indispensable to a complete geological education.

#### Arran.

General  
features.

The Island of Arran has been very often described, and by eminent Geologists. Jameson, Macculloch,

Necker, Murchison and Sedgewick, Oeynhausen and Von Dechen, have all written ably on the inexhaustible subject of this little world of geological phenomena; and were it not for a reluctance to add to this weighty literature, other voyagers would be unable to restrain themselves from describing some neglected but curious phenomena. The leading features of Arran are its mountainous and truly Alpine scenery in the Northern extremity, and the elevated plateaux of its Southern portion. These latter are generally composed of trap rocks, partly syenite, partly porphyry, partly greenstone, with many dykes of greenstone and pitchstone passing through the red sandstone strata which appear around the coasts. The highest Northern eminences are granitic mountains forming the nucleus of a great conical elevation of slate rocks, which, overlaid by the red sandstone formation, (see p. 609.) form a narrow but unequal zone round the granite. The small size of the Island combined with the elevation of the mountains (nearly 3000 feet) gives to the short glens a very sudden depth, and permits the cliffs to show the great curvatures of strata. Dykes and overlying masses of greenstone, felspathic and trap porphyry, various sorts of claystone and pitchstone, are seen abundantly both on the Eastern, Western, and Southern coasts; and so perfectly are all the phenomena exhibited, that it is difficult to imagine any space of the same limited extent more worthy of being studied for the purpose of understanding the mutual relations of pyrogenous rocks.

That the granite of this Island was upheaved in a melted state seems sufficiently demonstrated by the fact of its throwing veins through the surrounding slate rocks: this phenomenon may be very well studied at Tornidneon. That its elevation was subsequent to the deposition of the whole red sandstone system seems also proved by the curvatures which these strata have undergone. This would give for the elevation of the granite of Arran a period considerably later than that usually assigned to the principal part of the Highland mountains, and, perhaps, agreeing with the rising of the syenites of Malvern and Charnwood forest.

The granite is, as far as can be known, the oldest pyrogenous rock to be seen in the Island, for it is traversed by dykes of basalt and pitchstone, like those which cross the red sandstones. It is observable, however, that these dykes are most numerous at some distance from the granitic centre. At Corygills, at Lamash, and Tormore, they are exceedingly abundant in the red sandstone, while in the North-Eastern face of the Island, where that rock is nearer to the granite, fewer dykes appear, and about Loch Ranza the slate is still less divided by them. Perhaps we may venture to add another generalization; viz. that these dykes are most abundant beyond the line of violent flexure of the strata from their horizontal position. After measuring with care the directions and breadths, and noting the characters of forty-four dykes, chiefly of greenstone, between Brodick and Lamash, and also those at Tormore, it did not appear to the writer of this notice that any other dependence of the direction of those dykes upon the local centre of the granitic eruption could be traced.

While in the Eastern side of the Island, about Corygills, the dykes in the red sandstone are chiefly greenstone and basalt, with a sparing admixture of felspathic and porphyritic claystone and pitchstone, those of Tormore, in light coloured sandstone, are chiefly pitchstone, claystone, and trap porphyry. On both sides occur

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interposed beds of pitchstone, divided into columns; on the East are overlying greenstones in rude colonnades; on the West trap porphyry columns; on the East the claystone dykes are highly prismatic; on the West occur many interposed beds, and an arched vein of claystone. The pitchstone of the Eastern side is black or green, that of the Western coast often variously coloured and graduating to something like hornstone, or to claystone. It is, in one point, at Tormore, of that concretionary structure which reminds us of some kinds of obsidian and sphaerulitic traps.

Alterations  
of stratified  
rocks.

The effects of the pyrogenous rocks upon those in contact with them are less striking in Arran than in many other situations. No new minerals are produced in the slate where the granite touches it, nor in the red sandstones where they are bordered by the greenstone dykes. This hardening is very various in degree, and the causes of these differences are not very evident even upon the examination of many cases. The hardening effect is sometimes communicated to the distance of two or three feet into the neighbouring rock, but generally not to more than a few inches. The hardened parts sometimes stand up in narrow crests. Where dykes cross, it has been found that one of the planes of intersection of the greenstone dykes has been marked by the occurrence of a very narrow band of black pitchstone. The base of the pitchstone pillars of the interposed bed in Corygills is softened, where it touches the sandstone below, to a kind of kaolin.

It is impossible to say what was the geological epoch of the pyrogenous eruptions of Arran, further than that they were posterior to the whole red sandstone system there. If this be correctly taken by Murchison and Sedgwick to represent both the old and new red sandstone systems, they are later than most of those known in England, and, for aught we can tell, they may be as modern as the basaltic eruptions of the North of Ireland.

Geographical  
relation  
of pyrogenous  
rocks.

It is remarkable that, amidst all the profusion of greenstones, pitchstone, claystone, and porphyritic dykes, which appear a little remote from the granite, no granite dyke is seen; while in the granite, whose elevation seems to be the local centre of all those exhibitions, no hornblende or augite occurs. That granite and the trap dykes are of different antiquity has been shown before; but it seems also to be implied either, first, that at successive epochs different rocks lay melted under the same localities; second, that the local production of pyrogenous rocks is somehow governed by relations of level or distance, or subject to an obscure reciprocity of position. It seems worth while to follow out this idea. Along the Penine chain, the axis of dislocation shows, at points,

granitic and greenstone rocks, but very few mineral veins are wrought. The slopes a little removed from this mountain edge contain many valuable lead mines. The mining district of Shropshire, described by Mr. Murchison, appears related to the greenstone ridge of Corndon nearly in the same way; for though along this axis no mines occur, they abound in a line at a small distance parallel to it. Perhaps to these analogies we may add the instance of the diversified porphyritic masses which run irregularly parallel to, but removed from the granitic axis of Cumbria. Finally, to rise to a greater generalization, Von Buch's views of the relations of the granitic axis of the Alps and the augitic porphyries (melaphyre) along their Southern flanks appear to be decidedly analogous, and there seems at least thus much to be inferred from the points of agreement among these

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several examples of the relative position of ignigenous rocks, that the elevation of an axis or nucleus of granitic rocks was attended by very numerous fissures at a small distance removed, which, after some geological interval, were filled by rocks of a quite different nature from those which were erupted at the time of the first disturbance.

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## Granite.

It might be doubtful whether any granite visible in the British Islands could claim greater antiquity than the upper or graywacke slate rocks, except for the cases of alternating granite and mica slate, quoted from Mr. Weaver, p. 563. The granite of the Cornish chain in some places throws veins into the adjacent clay slates, and generally appears to change very greatly the nature of those rocks, so that we are compelled to rank it as a more modern product. The granites of Cumberland and Westmoreland, and those of the Grampians, if their age be judged of from that of the convulsions accompanying them, and from the veins which they throw off, must be pronounced to be of nearly the same antiquity. In the Island of Arran, the granite seems to be not so old as the red sandstone which overlies the carboniferous limestone; in the Alps it must perhaps be supposed to have been in fusion ever since the tertiary epoch.

Antiquity of  
granite.

A few years ago granite veins were considered as rare eruptions, but at present it is difficult to find a satisfactory example of any extensive tract of granite, without the occurrence of such ramifications through the neighbouring rocks. They occur in Cornwall, Cumberland, and Arran, in Ben Cruachan, at Strontian, in Glen Tilt, and generally throughout the Highlands. The same is true for the Continent of Europe; and perhaps we may now find a better example of the elevation of granite in a solid form, than that described by Murchison at the Ord of Caithness. This granite, on its Northern flank, supports the old red conglomerate, whilst to the South it occupies a cliff on and near the shore, the verge of which affords a remarkable breccia, compounded from all the beds of the oolitic series that occur on this coast. This breccia of sandstone, shale, and limestone, is tilted off from the granite wherever that rock protrudes upon the shore, whilst the strata are regularly developed where the granite recedes into the interior. No veins or portions of the granite are to be met with in or above the oolitic breccia, which, by its disturbed position, appears to fix the maximum of antiquity of the elevation of the granite not beyond the age of the coralline oolite.

Granite  
veins.

The granite veins of Tornidneon in Arran pass from Tornidneon a body of very coarse grained granite through nearly vertical laminae of dark quartzose clay slate; the line of junction dividing the whole side of a hill. One of the veins, enclosing fragments of slate, divides itself into branches, which cross the laminae of slate, cutting off both the quartzose and argillaceous laminae. The granite becomes much finer grained along the veins, and nearly in proportion to their smallness; so that in the narrowest veins it is nearly compact. Strings of fine grained granite divide the coarser sort. (See pl. vii. fig. 1.) (1826.)

In Glen Tilt, Dr. Macculloch has described numerous and valuable facts of this nature. At the bridge beyond Forest Lodge, granite, hornblende slate, and primary limestone are very curiously associated. Veins of red



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granite here divide the other rocks, and inclose fragments of them. The singular interlacements of the rocks here will be best understood by the sketch, pl. vii. fig. 2, taken on the spot in 1826.

1. Primary limestone laminated by hornblende and red felspar in curved lines or detached masses, round which the laminae of limestone bend, crossed by granite and red felspar veins.

2. White quartz rock and red felspar crystallized.

3. Felspathic rock, red, with layers of black hornblende.

4. Limestone laminated with felspar.

5. The same with less felspar.

6. Hornblende and felspar in layers.

7. Laminated limestone.

(a.) Red felspar vein--a little quartz.

8, 9. Hornblende, with layers, masses, and veins of white quartz, and red felspar, which substances often occur together, making binary granite of very large grain.

10. Limestone, with red granite veins.

11. Limestone, red granite veins, and white calcareous spar veins, which divide the granite veins.

12. Red granite, composed of red compact or crystallized felspar, white quartz, and black or grey mica, and incloses hornblende masses which are divided by veins of granite ramifying from the general masses of that rock.

Cornwall.

The extremity of Cornwall has long been famous for the great variety of curious phenomena connected with the granite veins which there divide the argillaceous slate, hornblende slate, and greenstone rocks, all included by the miners under the title of killas. So many writers of eminence, both English and foreign, have described and reasoned upon these occurrences, that it is difficult to select from the immense variety. The following is Mr. Majendie's account of the veins at Mousehole, three miles South-West of Penzance. (*Cornwall Geol. Soc. Trans.* vol. i.) "At this period the clay slate ceases, and the granite commences, forming a promontory which runs out in a Southern direction from the central ridge. The slate is of a grey colour; it is in strata nearly horizontal, but having a slight dip to the East; it increases in hardness near the junction. The granite, which is generally coarse and porphyritic from the large imbedded crystals of felspar, becomes here of a finer grain, with black mica and light flesh-red felspar. On the North it laps over the schistus. At this spot numerous granite veins, varying in width from about a foot to less than an inch, pass through the slate; the two principal veins proceed nearly East from the hill above, for more than fifty yards, until they are lost in the sea. One of these, not far from its first appearance, is divided and heaved several feet by a cross vein consisting of quartz intermingled with slate; fragments of slate appear also in the granite veins. The most remarkable vein, after proceeding vertically for some distance, suddenly forms an angle, and continues in a direction nearly horizontal, having slate above and below."

The killas at this place has much the aspect of greenstone, and it appears generally true that the clay slate is much altered in character round all the granites of Cornwall and Devon. (See Mr. De la Beche's *Geological Map, Devon*.) The veins of granite are generally most fine grained towards the walls. Von Oeynhausen and Von Dechen mention three principal veins at Mousehole, one  $3\frac{1}{2}$  to 10 feet wide; quartz veins cross the direction of the granite veins, and sometimes divide them

and apparently alter their character. Schorl occurs irregularly in the granite, and in some of the quartz veins. In other localities, veins of this mineral present interesting phenomena. The intricate character of the venigenous masses of Mousehole will be best understood by consulting the diagram, pl. vii. fig. 3, copied from the sketch of the distinguished Prussian Geologists above named.

At Cape Cornwall, a granite vein *heaves* a quartz vein in a direction contrary to the general law, stated in page 541. In the Lizard district granite veins divide serpentine.

### Felspar Porphyry.

The abundance and variety of felspar porphyry, in Ben Nevis great masses on the summit of Ben Nevis, and in the awful valley of Glen Coe, is familiar to every traveller in the Highlands; the porphyry of Ben Nevis has been shown by Von Oeynhausen and Von Dechen to have been erupted through the granitic basis of that mountain; the diversified porphyries along the vertical precipices of Glen Coe send veins through the subjacent granites, in number proportioned to the proximity of the situation to the great mass of porphyry. This rock is not columnar; (Macculloch;) it varies through every stage, from claystone to felspar porphyry, the different varieties being sometimes gradually and sometimes suddenly connected. Breccia, composed of fragmented claystones and porphyries, (like those on Ben Nevis, and some in Cumberland,) are often seen in Glen Coe.

In the mountain of Cruachan, which overlooks Loch Awe, the hornblende granite and schist rocks are traversed by a great variety of large felspar and trap porphyry dykes, and some changes of appearance happen to the clay and mica slate, very difficult to be described. Macculloch (*Geol. Trans.* iv.) describes the porphyry dykes as perpendicular, varying from 3 to 50 feet in breadth, traversing alike the schist and the granite veins which divide it, but not in any degree intermingling with either. Dykes of porphyry, of different kinds and colours, may run near or in contact with each other, but in all cases these and other dykes of basalt or trap porphyry are very distinct at the edges, though firmly united to the rock which encloses them. Pl. vii. fig. 4, shows veins of granite traversing the schist of Cruachan, themselves crossed by dykes of two kinds of porphyry. (*Geol. Trans.* iv. pl. vi.)

In the Cumbrian mountains felspar porphyries occur in many situations, and with a great diversity of character; some have a basis of translucent grey or green felspar, and included crystals of glassy felspar and quartz; others are composed of a red, opaque, granular felspar basis, and red felspar and quartz crystals; the basis of others is compact felspar or hornstone, and some have a dark but not basaltic base, with small white opaque felspar crystals. Most of them, like the amygdaloids and greenstones of the same region, occur in overlying masses as well as dykes, but real alternations of them with the slates can hardly be substantiated. They seem to have a Geographical dependence on the foci of granitic eruption, of a peculiar kind. They are not abundant in or very near to the granite of Wasdale, Skiddaw, or Shap, but they occur at small distances from each of those masses. The Valley of St. John's shows pale red felspar porphyry overlying slate, well crystallized red porphyry in Armboth fell, and various

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kinds of felspathic rocks under Helvellyn. Dykes of variable greenish porphyry divide the slates of High Pike, and a solitary red dyke ranges East and West of the granite of Shap fells. No porphyry occurs very far from the granites.

\* In North Wales felspathic porphyries appear so connected by alternate bedding with the slates, as to have been subjected to the same elevations and undulations of dip; and thus not only prove their high antiquity, but also suggest views as to the frequent recurrence of igneous action at the same points of the ancient bed of the sea during the period of the primary slates.

Cornwall.

Consistently with our views of the origin of the crystallized rocks, we may perhaps be right in believing that all the complicated, wholly or partially, crystallized rocks, composed of felspar, quartz, and mica, which are included between and which traverse the real slaty rocks of Cornwall, are either the result of submarine eruptions during the formation of the slate; or of the subsequent action of the heated granitic masses upon the killas; or of posterior eruptions of melted rock into fissures caused by convulsion, or of some gradual conversion and transfer of mineral ingredients, such as we know to have occurred.

It is hazardous to reason on phenomena so remarkable as those of Cornwall, without reference to other districts; nothing but prejudice or indolence will permit Geologists, acquainted with other districts, to neglect the singular and curious facts connected with the Devonshire and Cornish chain. We may freely admit that they, in some cases, point to agencies not yet familiar to our philosophy; that a full examination of the whole series of granites, porphyries, serpentines, and killas, and of the disseminated and venigenous minerals in them, will kindle a brilliant light in the most secret laboratory of Nature; but one thing is wanting, an exact description of all the characteristic facts observable in each particular case, without the adornment of theory, or the disarray of new nomenclature. (See Conybeare, Buckland, and Sedgwick, *Geol. Trans.*; the *Trans. of Cornish Geol. Soc.*; and Dr. Bouse's recent volume.)

#### Syenite.

Malvern.

The syenite of Malvern is not older than the old red sandstone, which it throws off from its slopes and penetrates by a lateral extension or dyke, nor so young as the new red sandstone which lies level at its feet; the same limits of age must be assigned to the similar rocks of Charnwood forest, which appear under very analogous circumstances. The partially syenitic rocks of Carrock fell in Cumberland, may, very probably, be older. We shall not assign this name to the variable rock of Red Pike and Scale Force: according to Weiss, the syenite of Weinbola near Meissen is superimposed on the green sand system. The Malvern hills, long since described with much ability by Mr. Horner, and a dyke apparently dependent on them lately investigated by Mr. Murchison, will serve to illustrate the phenomena attending syenitic extrusions.

The picturesque chain of the Malverns rises at its centre to 1444 feet above the sea, and looks down over a vast and beautiful region. On the Eastern side the descent is abrupt to plains of horizontal new red sandstone, on the Western more gradual and diversified by ranges of woody hills whose bearing is parallel to that of the chain. Beyond are the slate mountains of Wales.

Many small narrow valleys run to the East across the line of the chain.

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The verdant surface of these hills, and the circumstance that the pyrogenous rocks are very much decomposed and fissured near the surface, prevents very frequent observation. The great mass of the rocks is of a syenitic rather than granitic character, varying, however, much as to the relative proportions of hornblende, mica, and quartz: the felspar is usually red, epidote, magnetic iron, pyrites, and other minerals occur, and the aspect of the rock is sometimes that of greenstone. Veins of granite traverse the neighbouring rocks. Veins of sulphate of barytes, calcareous spar, and epidote, red hematite, &c., occur in the syenitic rocks.

The stratified rocks which are dislocated along the line of the Malverns are best seen on the Western slopes, the oldest of them belongs to the fourth group\* of the greywacke series of the Welsh border. (See p. 567.) The sandstones of this and the limestones and shales of the superior groups are partly vertical, or partly overthrown to the West, so that for some distance to the West the series of strata appears inverted, and the really newer rocks come out from under the older. (*Geol. Trans.* vol. i.) Much local confusion and disturbance of declinations accompany these general indications of violent upward heaving along the axis of the chain. Mr. Horner's very judicious reflections on the bearing of the phenomena of the Malvern upon the then prevalent discussion of the Wernerian and Huttonian Theories of Geology, will be perused with great satisfaction and pleasure as anticipating many of the clearest arguments known in the present advanced state of the Science. As the unstratified rocks have been thrown up along a line from North to South, the bearing of the elevated strata ought, in general, to be parallel to that line, and this has been shown to be the case: the force would be greatest at the point where the unstratified rocks burst forth, and accordingly we find the strata there generally vertical, or even thrown back and in some degree inverted.

The same phenomena of inverted strata are observed by Mr. Murchison parallel to the Abberley hills, which are on the prolongation of the Malverns; and we are indebted to him for an interesting notice of a dyke of dark green syenitic rock, at Brockhill near the Teme, composed of hornblende, felspar, and quartz, eight paces wide, directed West 5° North, and East 5° South. The syenitic rock is prismatic at the sides, the prism lying across the dyke, whose walls are formed of old red sandstone, here of a green tinge, and marls. In contact with the dyke and for 20 feet distance the sandstone is hardened, is of a deep purple colour, and has lost its mica; the marls are altered by the diffusion of carbonate of lime through their mass. This dyke is considered as a lateral effect from the great North and South axis of igneous rocks of the Malvern and Abberley hills.

#### Hypersthene Rock or Hypersthene Syenite.

Hypersthene rock forms the pinnacled mountains of Cuchullin, part of Carrock fell in Cumberland, certain dykes in Radnorshire, and is not unknown in Cornwall;

\* In the *Phil. Mag.* for June 1834. Mr. Murchison has published a new arrangement of these groups, in which the second and third groups are united.



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it also occurs in Yorkshire in veins passing through the basalt of the carboniferous limestone series. The exhibition of hypersthene rocks in the Valteline has been described by M. Necker.

This rock may be very generally described as a syenite, of which the felspar is pale flesh-colour, white, or greenish, and the hornblende is replaced by hypersthene, either in very distinct, large crystals, or small concretionary masses. In the latter case it can hardly be distinguished from common greenstone. In Cornwall, Radnor, and Cumberland this rock may be admitted to be of later date than the greater part of the slate system; in Yorkshire it is contemporaneous with the great basaltic formation of the carboniferous epoch; in the Isle of Skye it is probably more recent than the oolitic era; in the Alps it forms a part of the mineralogical axis, and may have been thrown up even since almost the whole tertiary strata of the basins of Europe.

The Valteline.

M. Necker, in his account of the Valteline, establishes the fact, that the granitic eminences which rise along the axis of that singular valley of elevation, pass by degrees to common syenite, and afterwards to syenite with hypersthene, in large, small, or even minute crystals, of black or green colour, and metallic reflections. The felspar has a violet tinge. The greater and hypersthene axis of the valley is coincident with the central line of the great chain of the Alps, from South-West to North-East, and the stratified rocks are vertical on each side, for some distance; afterwards they take opposite dips to the North-West and South-East. The order of succession may be stated to be gneiss, mica schist, changing to talcose and chloritic schist and clay slate. Veins of fine grained granite pass through the hypersthene rocks and through the mica schist, sometimes holding fragments of this latter, and quartz veins with black tourmalines divide the granite.

Skye.

The Cuchullin mountains in Skye, rendered classical by Macculloch's descriptions, surround the desolate lake of Coruisk, a grand amphitheatre of steep and barren rocks, which decompose so little as to yield neither sand nor gravel to the torrents. A great variety of appearances is presented by the mixture of the felspar and hypersthene in these rocks, as to crystallization and colour. In some localities the mass is fine grained, and in others graduates to common syenite or greenstone. Von Oeynhausen and Von Dechen state that the hypersthene rocks pass into compact greenstone; and that the common syenite lies on the hypersthene rock, with an abrupt and distinct junction. One of the most interesting facts connected with this group of rocks is the transmutation of the lias into white granular and compact limestone, where it is in contact with the syenite and trap rocks. This effect happens more constantly at the junction of the lias with syenite than with greenstone or trap; in the latter case it sometimes happens, sometimes not. The hypersthene rock seldom adjoins the lias; where it does, like greenstone or trap, it both intersects and covers it.

#### *Gabbro, Granitone, Euphotide, Diallage Rock Serpentine.*

It is to M. Von Buch that we are indebted for pointing out the importance of the rock, composed of saussurite, or felspar and diallage, called gabbro, or granitone, in Northern Italy. The abundance of serpentine in the Pyrenees, Apennines, and other parts of the South of Europe, has long been remarked. Diallage rocks are

equally abundant, often occur in connection with the serpentine, and there is now no doubt as to the fact that these two rocks are very intimately related. Few conclusions of this nature appear better authenticated by observation than the gradation of diallage rock into serpentine, in the Alps, the Apennines, Corsica, and Cornwall. Gabbro has been employed in architecture by the Romans, and by the family of Medicis at Florence. The town of Vienna is said to be paved with it.

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Generally, observers agree in representing both gabbro and serpentine as unstratified rocks. When portions of them are included between strata of gneiss, mica schist, &c., they may be viewed as interposed masses. But Macculloch positively affirms that in Unst the stratification, both of diallage rock and of serpentine, is certainly evident; and he compares the cases where no stratification can be traced in the latter to analogous instances in primary limestone. The latter, however, is by far the most abundant case; and perhaps, taking into account the circumstance that in Unst the rocks alternate and graduate into micaceous, chloritic, and argillaceous schists, we may reasonably inquire whether the stratified varieties of diallage and serpentine are not recomposed rocks altered, like some gneiss, by subsequent application of heat.

Stratification of serpentine.

In the Northern Apennines, Brongniart has remarked the following general order of succession downwards. 1. Serpentine. 2. Diallage rock, in the upper part assuming the aspect of serpentine, (at Rochetta, North of Borghetto, near Spezia,) consisting partly of red crystallized limestone. 3. Jasper rock in thin laminae. Below these are limestones and marly schists, common in the Apennines. In Monte Ramezzo, North-West of Genoa, the serpentine is placed on limestone and talc schist, the limestone is in thin tortuous beds, and is as it were dissolved with the shining slate and steaschist. The direction of the serpentinous masses in the Northern Apennines, to which the elevation of that part of the range is ascribed, is East South-East, which is the same as that of the Pyrenees, and of some serpentine rocks about Como.

#### *Greenstone.*

Scotland has been long and not unjustly considered classic ground for the pyrogenous rocks. We shall take as an example of the occurrence of greenstone, the phenomena in the vicinity of Edinburgh, which have contributed so powerfully to support the philosophical fame of Dr. Hutton. The interesting eminences of Arthur's Seat, Salisbury Craig, the Calton Hill, and Edinburgh Castle, are all composed of trap rocks associated with various sandstones and shales of the carboniferous system, and the labours of Art have added to the admirable exhibitions of Nature.

In Salisbury Craig is a very fine section of unstratified greenstone enclosed between stratified sandstone, conglomerate, shale, and ironstone nodules, and it is easily seen that both the igneous and sedimentary rocks are altered at their formation. Masses of sandstone and conglomerate, of various forms and magnitudes, are insulated in a confused manner within the greenstone, and portions of greenstone interposed among the sandstones. No dyke appears, but small veins of calcareous spar, occasionally metalliferous, cross the line of junction. The accompanying drawings and references will sufficiently explain the most interesting phenomena observed.

Salisbury Craig.

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Pl. vii. fig. 5, gives a general view of the face of the cliff, as it appeared to the writer in 1826. The letters of reference, *a, b, c*, mark points of which details are given below. On a nearer examination, the point *a* shows greenstone gradually changing to a red colour and finer grain near its upper surface, on which rest beds of sandstone, ironstone, and shale, as under.

1. The upper part of a greenstone mass, fine grained and of reddish colour. Veins of calcareous spar, with micaceous iron ore, divide the upper part of this mass, and pass through Nos. 2 and 3 above.

2, 3. Mass of petro-silicious sandstone, mixed with softer green portions.

4. The same sort of hardened sandstone, with less of the softer parts, (here and there a purple tinge.)

5. Argillaceous, compact, hard shale of a purplish or green colour, and subconchoidal fracture.

6. Red argillaceous ironstone in green shale.

7. Sandstone beds, reddish and indurated.

At the point *b* (fig. 6) a nearly similar series of alternating stone and shale rests on very similar trap. A portion of sandstone is engaged in the trap, and other signs of violent intrusion occur.

At the point *c* hard red sandstone flags, without ironstone, rest on reddened greenstone.

A large quarry at the South end of Salisbury Crag affords an excellent section of sandstone beds below the greenstone. Fig. 7 and 8 are taken from this quarry.

In fig. 7, the greenstone, reddening below, rests on jasperized sandstone, which is much broken and confused in places; below this is green shale, covering red and white sandstone with conglomerate. Fig. 8 shows portions of sandstone enclosed in the trap, which grows redder towards the contact with the strata below. The aspect of a portion of sandstone fairly enclosed in trap is seen in fig. 9.

Some late observations of Lord Greenock on the appearances presented by a section of the compact greenstone and sandstone strata in the Castle Hill, Edinburgh, show the effect of convulsions acting upon both of those rocks since the eruption of the lithoid lava. At some points of this hill the usual transformations of the sandstones, &c. happen in contact with trap, but in one place beds of sandstone and marl are seen in a state of great disturbance, thrown in angular positions upon tabular greenstone, and not in the slightest degree altered as to hardness or aggregation at the junction. Possibly, the explanation which applies here, viz. that the junction of the igneous and stratified rock has been occasioned by convulsive movements, which have lifted them both in a solid form, may be found applicable to some other cases in which trap rocks appear to exercise no transforming influence on the contiguous rocks.

#### Basalt.

The researches of Dr. Berger, Dr. Buckland, and Mr. Conybeare, on the North-East of Ireland, have furnished a highly interesting Memoir in the *Geol. Trans.* vol. iii. from the pen of the latter Geologist. The coast between Belfast Lough and Lough Foyle is one boundary of a large tract reaching Westward to Lough Neagh, and including the river Bann, which is almost wholly occupied on the surface by basaltic rocks rising at intervals to eminences of 1320, 1820, and 1864 feet above the sea. Under this immense overlying mass of basalt are found several members of the English series

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of strata not known elsewhere in Ireland. 1. Chalk, agreeing with the lower beds of the English series. 2. Mulattoe, an Irish name for the green sand of English Geologists. 3. Lias limestone. (without any other rock of the oolitic system.) 4. Beds of red marl and gypsum salt, resting on variegated sandstone. 5. At the North-Eastern and South-Eastern extremity, coal measures, consisting of red sandstones and shales with inferior coal, appear below all the other strata. The mulattoe and lias are often wanting in the section. The superincumbent basalt is estimated to have an average thickness of 545 feet, (in Benyavenagh it is 900 feet, in Knocklead 980 feet,) and its superficial extent 800 square miles.

The phenomena presented by the basalt, exposed along so great a length of coast, are various and remarkable, and we are not only delighted with the magnificent colonnades of Fairhead, and the geometrical pavement of the Causeway, but instructed by the clear exhibition of the effects of dykes dividing both the congenerous basalt above and the calcareous strata beneath.

The immense mass of trap rocks in this district exhibits, besides basalt, which is the most abundant material, greenstone, clinkstone porphyry, wacke, and red ochre. Near the Causeway, the cliffs, according to Dr. Richardson, consist of alternating basalt and red ochre, in the following order downwards.

1. Basalt rudely columnar, 60 feet.

2. Red ochre or bole, 9 feet.

3. Basalt irregularly prismatic, 60 feet.

4. Columnar basalt, 7 feet.

5. Intermediate between bole and basalt, 8 feet.

6. Coarsely columnar basalt, 10 feet.

7. Columnar basalt, the upper range of pillars at Benmore Head, 54 feet.

8. Irregularly prismatic basalt. In this bed the wacke and wood coal of Port Noffer are situated, 54 feet.

9. Columnar basalt, forming the Causeway by its intersection with the plane of the sea, 44 feet.

10. Bole or red ochre, 22 feet.

11, 12, 13. Tabular basalt, divided by thin seams of bole, 80 feet.

14, 15, 16. Tabular basalt, occasionally containing zeolite, 80 feet.

The stratified rocks in contact with the trap have undergone remarkable changes in several localities.

At Portrush, the trap (a rudely prismatic greenstone) overlies and perhaps alternates with a flinty slate, which contains numerous impressions of ammonites, belonging to the lias shales. This transformation of lias shale, which reminds us of the more extensive phenomena of the same kind in Savoy, was formerly adduced as an argument for the aqueous origin of basalt! Most of the alterations of stratified rocks on this coast are effected by basaltic dykes, which divide both the overlying masses of trap and the subjacent strata.

At the foot of the hill called Lurgethan, basaltic dykes traverse the red sandstone conglomerate, which is indurated near the contact so as to resemble compact hornstone.

The coal measures, underlying the basalt of Fairhead, are crossed by dykes which have changed the ordinary shale into flinty slate, hardened and pyritized the sandstone for 15 yards, and converted the coal to a cinder. The chalk is affected by many dykes to such a degree as to be converted to a real marble, for 10 feet or more from the side of the basalt.

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The order of effects is first a yellowish tinge of colour, then a bluish-grey colour and compact texture, then a fine-grained arenaceous aspect, next a saccharine granulation, and finally close to the dyke the chalk is altered to a dark brown crystalline limestone, with flaky crystals as large as those in primary limestone. The flints in the altered chalk assume a grey-yellowish colour; the altered chalk is highly phosphorescent when heated. Examples occur near Belfast, at Glenarm, in Rathlin, and other places. Near the top of the stratum of chalk which crowns the cliffs of Murloch Bay, is an interposed bed of wacke 5 or 6 feet thick. For proofs of local violence accompanying the exhibition of the basalt, and many interesting details, the original Memoirs may be consulted.

The basaltic formation of Upper Teesdale in Yorkshire has been described by Professor Sedgwick, and its continuation through Northumberland by Mr. Hutton; and we can bear witness to the merit of their researches. The great mass of basalt (called Whin Sill) lies in a pseudostratum of most irregular thickness, enclosed among the strata of the carboniferous limestone series, generally in one particular part of the series, so that in the valley of the Tyne its place in the section is constant, and we think it occupies generally the same situation in Teesdale, though in Weardale another layer of basalt occurs. We cannot doubt that it was erupted from several local centres or lines, and that its thickness at different places was affected by their proximity to the eruptive channel. In the short space of six miles, from Caldron Snout to Hilton Beck, its thickness is diminished from 200 or 300 feet to 24 feet, and further South it disappears totally. But to the Northward the range is (interruptedly?) continued to the sea-coast of Dunstanborough.

No dykes pass from this mass (in Teesdale) into the rocks above or below; so that a first view of the case suggests the belief that it was poured out as a mass of submarine lava upon the yet incomplete deposit of the carboniferous limestone. Professor Sedgwick, however, (*Camb. Phil. Trans.*) maintains that it was injected from below amongst these strata, and that it penetrated between the planes of the strata by violently uplifting them.

The strata in contact are affected by the basalt in several ways, which may be well seen about the high force. The subjacent shales are prismatized, so as to be mistaken for basalt, generally much debilitized, so as to become grey or whitened, and rendered brittle by condensation, but not much hardened. The sandstones are in several places highly hardened, rendered brittle and full of fissures, and much whitened. The limestones below the shale are remarkable for having their top bed full of iron pyrites. Those above, but not in contact with the basalt, are for a large tract of country totally changed from a full blue, hard, rather crinoidal limestone in the first degree to a pale blue, crystallized, soft marble, and in the extreme to a loose, granular, saccharoid rock, in which, nevertheless, some traces of organic remains (a crinoidal column) remain. But the most remarkable effect is the generation of garnets in the contiguous shale under the basalt of Cronkley scar; a case analogous to the one described in connection with the dykes of Plas Newydd by Professor Henslow. (*Geol. Trans.*)

The igneous rocks themselves are chiefly a fine-grained black basalt, changing to a coarse-grained va-

riety of the same ingredients. Contemporaneous veins of very beautiful hypersthene and augitic trap pass through the basalt in several points, and it is traversed by a few productive lead veins.

The connection of several very remarkable and extensive basaltic dykes with this great "Whin Sill" is rather assumed than proved. In fact, there is no evidence of any one of these dykes being traced into the Whin Sill, and as some of them pass into the upper coal measures, and one divides magnesian limestone, lias, and oolites, we prefer to consider them of different Ages, though certainly related to the same local centre of igneous expansion. Successive injections of similar igneous rocks, at remote geological intervals, seem to be indicated by the phenomena.

These dykes pass in directions to the East North-East, East South-East, and nearly East, and the lines which they take are so straight through all sorts of rocks, their respective breadths, and the quality of the rock in each, so nearly uniform, though in these particulars they differ from one another, that, considering their extraordinary length, we may safely rank them as amongst the most remarkable phenomena of English Geology. The Cleveland or Cockfield dyke, in particular, ranges for seventy miles through the coal series, (where it chars the coal, hardens the sandstones, and debilitizes the shales,) the magnesian limestone, the lias shales and sandstones of the oolite series, which are affected like the coal system below. Generally it is a nearly vertical dyke, but at Cockfield fell is subject to oblique expansions of a singular kind.

The dyke which passes East North-East is remarkable for having a small vein of lead ore running by the South-East side of it, and for converting the shales through which it passes to the state of a soft, whitish shale, called pencil bed, like those in connection with the Whin Sill. It does not cut through the magnesian limestone.

#### *Melaphyre, Pyroxenic Porphyry.*

The history of this rock, which has a base of augite or pyroxene, holding crystals of felspar, is indissolubly associated with the name of Leopold Von Buch, who, by a series of observations, chiefly founded on a survey of the Southern flank of the Alps, has been led to form the remarkable opinions: 1. that the elevation of the Eastern range of the Alps, since the tertiary epoch, was contemporaneous with and dependent on the eruption of melaphyre; 2. that the dolomites of the Alps were produced from ordinary limestone at the same time and with the same dependence. This line of dolomites and melaphyres extends (interruptedly) from Bleiberg to Lake Lugano; but the occurrence of so many masses of dolomitic limestone in other situations than where melaphyre shows itself, must render inconclusive the inferences drawn from their connection in the Alps. Neither is this connection always very evident. On the contrary, even at Lugano, it is rather near the augitic rock than in contact with it that the limestone is dolomitized. Von Buch's own Map and sections (*Ann. des Sci. Nat.* tom. xviii. pl. vii.) would hardly lead to the opinion that the dolomitization of the limestone was especially due to the presence of melaphyre. For between the dolomite and melaphyre of the peninsula of Lugano, mica schist and another kind of porphyry intervene: and on Monte Argentera, the limestone which

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lies upon the melaphyre is not dolomitized. De Beaumont admits that it is even rare to find the dolomites near Lugano in actual contact with melaphyre.

It would, however, be unjust to Von Buch to reject the hypothesis on this account. He himself says it is to gaseous eruptions accompanying the pyroxenic eruption that we must ascribe the alterations of rocks.

The influence of these exhalations might be felt far from the main fissures occupied by melaphyre, and De Beaumont generalizes the phenomena so as to refer the production of dolomite to the exterior line of fracture of the primary rocks; that is, to the line which now divides the undisturbed from the disturbed rocks. See page 761.

The view is thus entirely changed, and certainly rendered more philosophical. Whatever may be its fate in this amended form, Geologists will have been taught by it to investigate generally what connection there may be between certain phenomena of alteration of rocks, certain lines of disturbance, and particular erupted mineral aggregates; and thus the field of research into the conditions of the local metamorphism of stratified rocks is greatly widened, and brought into nearer relation with the speculations concerning general alterations of the primary strata around granitic nuclei and axes of elevation.

#### Claystone.

In the cliffs of Corygills (Arran) are several claystone dykes. One of these slopes at a considerable angle through the sandstone cliff, and, being very wide, shows a columnar structure in the middle rectangled to the plane of the dyke; along the sides it is slaty. Between the columnar porphyry of Drumadoon and the Coves on the West side of Arran may be seen no less than five interpositions of claystone among the sandstone strata, mostly exhibiting a rude prismatic structure.

Near Tormore is the celebrated arched vein or dyke of claystone represented by Macculloch, and considered as composed of ellipsoidal concretionary layers by Boué. It is redder and softer in the middle than at the sides; it divides strata of red clay and white sandstone. Great variety of claystones occurs in the Pentland hills. (Professor Jameson, *W. H. Trans.* vol. ii.)

#### Claystone Porphyry.

Trachytic porphyry, (Boué,) clay porphyry, as it is termed by Jameson, occurs on the Western shore of the Island of Arran in considerable variety. It appears in the cliffs in huge overlying masses, and on the sandstone shores in dykes of great width. At Drumadoon many interesting exhibitions of it occur. We extract the following brief notices from a journal of observations in 1826.

A dyke (a) of clay porphyry 20 feet wide, ranging South 40° West, includes large modified felspar crystals, which are sometimes nodular in external figure. On the South-East side is a contiguous vein of greenstone. The porphyry encloses masses of greenstone; it is not prismatic. A huge mass (b) of clay porphyry, like a dyke or rather interposed bed, dipping South, has on the South a layer of more basaltic aspect, the two being united in one specimen. In the fine range of clay porphyry columns at Drumadoon, which are 60 or 80 feet high, occurs a dyke of greenstone passing in a line of

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double flexure obliquely through the pillars. At the base of these columns is a layer of more decidedly basaltic rock with few crystals of felspar, through which the same prismatic structure passes. Towards this great mass the dyke (a) tends, and is said to join it. A very wide dyke of clay porphyry, ranging North 60° East, (beyond the Coves,) has greenstone on each side, and also encloses greenstone.

#### Amygdaloidal Trap.

The Hill of Kinnoul, one of the most remarkable masses of trap rock in Scotland, rises near Perth, from out of the great area of red sandstones which lie against the primary strata of the Highlands. Its height above the plain of the Tay is stated by Macculloch (*Geol. Trans.* vol. iv.) to be 600 feet, and it shows precipitous faces to several quarters. The greater part of the hill consists of an amygdaloidal rock, whose basis varies from well-characterised basalt to wacke. The substances which impart to the rock its amygdaloidal character are, green earth, calcareous spar, quartz, and calcedony. Green earth, or chlorite, occurs in nodules generally small and round; it also invests the roundish nodules of calcareous spar, which are crystallized within but externally accommodated to the shape of the cavity in the rock, or to the crystals of quartz which sometimes line the cavity. The spar is sometimes crystallized at liberty in a cavity of quartz or agate.

The quartz is found to vary by several shades into agate and calcedony, which latter sometimes appears in a stalactitical form hanging downwards in the cavities of the amygdaloid. Alternating zones of quartz and calcedony sometimes appear in the same nodule; amethystine quartz also occurs, and we have in Kinnoul almost every variety of angularly zoned agates. Veins as well as nodules of calcareous spar and quartz divide the rock, and more rarely sulphate of barytes, chert, and agate. Veins of heliotrope have also been found, but without the red spots. Macculloch thinks there is not the least reason to doubt that the substances now filling the cavities of the amygdaloid have been introduced at some period since the cavernous aggregation of that rock from a state of lava.

Shales and sandstones are hardened and altered, and much confused at their junction with the trap. A remarkable case of seeming prolongation of thin masses of the shale into the substance of the trap, so as to resemble veins, is described and represented by Macculloch. (*Geol. Trans.* vol. iv. pl. xi.) In these seeming veins the laminated texture of the schist disappears.

Alternations of amygdaloid and sandstone are frequent about Oban.

#### Wacke.

Respecting this softest of the trap rocks we shall only observe, that in the Calton Hill, Edinburgh, it forms part of those variable masses, which sometimes may be called amygdaloid, sometimes porphyry, and not unfrequently assume the aspect of breccia; being likewise traversed by numerous small veins or strings of calcareous spar. In the superior and Eastern parts of this hill wacke alternates with bituminous shale and nodules of argillaceous ironstone, in many repeated strata dipping to the East. At the surfaces of junction there sometimes appears a gradation from one rock to

the other; and it does not appear that any decided marks here occur of the action of heat upon the shales.

### *Pitchstone.*

As before observed, pitchstone occurs in the Isle of Arran both in dykes and interposed beds among the sandstone strata. The Western coast is particularly interesting in this respect. The same cliffs which exhibit so many claystone masses alternating with sandstone, contain also parallel short bands of pitchstone probably connected with the neighbouring dykes. One of these dykes, about 30 feet wide, is curiously mixed with hornstone, and for the most part bordered along the sides by greenstone. The disposition of these substances in the fissure will be understood by reference to the horizontal plan, pl. vii. fig. 10, where the letters H, P, and G are placed against the hornstone, pitchstone, and greenstone, respectively. The pitchstone is generally of a dark green colour, fissured longitudinally into rude prisms, which are jointed transversely at about two feet distance, or concreted into smooth conical masses. It seems to pass gradually into the hornstone, which is laminated parallel to its bounding surfaces. The dyke appears in one place to deviate from its vertical course and to go under a portion of the sandstone. A greenstone dyke, which is nearly right angled to the course of the pitchstone, is shifted by it.

In another dyke, one side is yellow pitchstone closely approximating to claystone, within this light green and red stripy pitchstone, then silicious splintery stone in irregular masses, (hornstone,) and the opposite side is greenstone. Another of these curious dykes is green pitchstone on each side, then red pitchstone, and in the middle dark grey hornstone.

The pitchstone bed at Corvills is 15 feet thick, and a dark green or black rock, enclosed between strata of sandstone, which are hardened towards the junction. The pitchstone is marked by lines parallel to its nearly level surfaces, and these are crossed by the smooth distant vertical faces of prisms. The lower part is porous; between it and the sandstone beneath is a white crumbly or fragmentary mass soft as steatite, which it much resembles.

### *Trap Tuff.*

#### *Porphyritic Breccia. "Volcanic Sandstone."*

Re-aggregations of the disintegrated or fragmented materials of trap rocks are generally known under the vague name of trap tuff and compared with volcanic tuff, sometimes without much reason. Amongst the slaty rocks of Cumbria, in Glen Coe and Ben Nevis, fragments of felspathic and porphyritic rocks are frequently found united into a solid breccia; under Arthur's Seat and in the Calton Hill recomposed irregular strata, chiefly derived from fragmented rocks of igneous origin, appear associated with ordinary greenstones, porphyries, and basalts. In many instances these have no just claim to be ranked with the pyrogenous rocks, but should be transferred to the class of tumultuary and local aqueous deposits: the circumstance that the principal portion of the ingredients is of igneous origin, is not probably confined to these rocks, but is often, perhaps with truth, ascribed to the whole mass of sedimentary deposits from water.

In the vicinity of Oban, in juxtaposition with some

interesting amygdaloids and altered shales, sandstone beds, composed of the grains of disintegrated trap rocks, are found resting on conglomerate, amongst whose pebbles are granite, porphyry, quartz, red and white amygdaloid, fine-grained basaltic trap, sandstone, jasper, &c.

Mr. Murchison has recently found, along the South Wales border, many examples of the occurrence of sandstone composed of the ingredients of trap rocks. A little removed from the steep slopes of the Wrekin and Caer Caradoc, rocks of this kind occur in beds, and contain organic remains, but in all respects of composition strongly resemble greenstone. They are noticed by Aikin. At the Southern extremity of the Wrekin, the stone is of a dark green colour, and is evidently composed of the ingredients of greenstone and syenite with a few scales of mica. Near the Caradoc these beds contain much decomposed felspar. They are part of the 4th system, p. 568, of the fossiliferous greywacke of Wales, and are attributed to submarine eruptions of volcanic substances in such a state of disintegration as to mix with the sea water, and be diffused over considerable breadth of the bed of the sea.

### SECTION 4.

#### *Mineral Veins.*

The circumstances attending the occurrence of mineral veins in the rocks, their intersections with each other, and the arrangement of their mingled metallic and sparry contents, have been sufficiently studied to ascertain that these valuable elements in the adaptation of our Planet to the wants of its inhabitants have been subjected to a great variety of processes depending possibly on one general law, but greatly modified, both in combination and energy by local and periodical conditions. In the vague language of imperfect Science, we say, many causes, separate or variously combined, have been concerned in the production of mineral veins; and it is probable that the most advantageous mode of investigating their origin, consists in the attempt to infer from the mass of facts already brought together what are, respectively, the spheres of action and limits of intensity belonging to the several processes concerned; and afterwards, from a more general contemplation of these processes in their various degrees of combination, rise to a comprehensive notion of their connecting laws and general cause.

This is not the mode usually followed by writers on mineral veins. Neglecting the general fact of the complication of the phenomena, they have been mostly anxious to try their bearing individually, or in mass, upon the perfectly general question of igneous or aqueous agency, and thus nothing was explained. A vast abundance of minute information of veins has been irrecoverably wasted; and the experienced miner laughs at the reasoning of the half-informed Mineralogist, contemptuously rejects his theory of veins, and contents himself with believing that the facts are inexplicable. This dissociation of observers and reasoners is the true cause of the comparatively small advantage which has been derived to Geology from the immense and various mines of the British Isles; on the one hand we have the greatest possible variety of phenomena, on the other the full extent of the resources of chemical and mechanical philosophy, but these have not been combined. If the zoological principles of Geology are better established

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and more fertile in deductions than the mineral principles, it is not because our knowledge of organic nature is more advanced than the science which treats of the constitution and agencies of inorganic matter, for the contrary, perhaps, is true, but because in the one case the ancient effects and the modern laws of action have been brought into mutual illustration, in the other deprived of all connection.

In order to prosecute investigation according to the principles which we have stated to be the best, we must limit our inquiry to those subjects most distinctly connected with metallic accumulations in the rocks. To support inferences concerning the general laws of processes which have produced mineral veins, we may with great advantage include the history of basaltic and granitic, and porphyritic dykes, but the discovery and estimating of the processes themselves, only those effects must be examined in which they are especially concerned.

Though at several points the distinction between rock dykes and mineral veins is imaginary, they are in general clearly contrasted by the nature of the substances which they contain, in the former case crystallized minerals of the same kind, those of the interior masses of consolidated rock, and those of the dykes are evidently ramifications, in the latter case substances which are not known to exist in nature except in these situations and in other very similar ones, not directly related to them by position, and crystallized earthy minerals, seldom of the same kind as those which occur in any of the rock dykes. To this general rule quartz is one of the most striking exceptions; yet even in this instance it is remarkable that the quartz of veins is of a very different aspect from that mingled with the ingredients of granitic and gneiss rocks. We must therefore take the presence of quartz as a criterion and certain non-metallic substances, usually associated therewith, and commonly called vein-stuff, as the leading characteristics of the mineral veins whose history we are now to examine, and connect with these all other cases of metallic aggregations or occurrences of the vein-stuff which seem referrible to the same or analogous processes.

The view embraces the following points of research. 1. What substances are found in mineral veins and repositories. 2. The manner of their aggregation or mixture. 3. The situations of their occurrence. 4. The relations between frequency, arrangement and contents of the veins, nature, age, and position of the rocks in which they occur.

#### *Substances in the veins.*

What substances, &amp;c.

The simple minerals which occur in veins and analogous situations, are far more numerous than those which are found as component parts of the rocks. Igneous rocks, and especially those of modern volcanic origin, hold a very great variety of non-metallic substances, some of which also occur in veins; but it is almost exclusively in this latter that we are to seek the metals in their pure state, alloyed with one another, or mineralized by combination with sulphur and other combustibles, with oxygen, chlorine, and other gases, or converted into salts by union with various acids. Every elementary substance yet discovered by Chemists exists in the earth, and it is probable that none of these are entirely absent from the solid contents of mineral veins; though this has not yet been shown to be the case

for iodine and bromine, which seem universally present in the modern ocean, and azote, which appears in an especial manner devoted to the atmosphere and to the organic portion of nature.

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The metallic substances seldom occur pure, sometimes in alloys, similar for the most part to those now producible by the Chemist, as silver, antimony, cobalt, nickel, iron, with arsenic; silver and nickel with antimony; lead, gold, silver, and bismuth with tellurium; silver with mercury, platinum with gold, &c. The only known circumstances which stand as antecedents to the production of such alloys, is heat, produced by either chemical or electrical action, and perhaps there is no single fact, connected with the theory of veins, on which the conclusion of the influence of heat in their production might be more securely based. The rare occurrence of pure metals affords an argument perhaps of less force, but perhaps we may draw the same inference from the very numerous class of metals mineralized by union with combustibles, as sulphur, phosphorus, carbon, selenium, &c., the formation of which, according to the state of our knowledge of chemical forces, heat would appear to be directly necessary.

We cannot apply this general argument to the case of the metallic oxides, which are very prevalent in veins, because in the first place, these are produced under various relations to heat, moisture, and contact with gaseous substances; and, secondly, have various degrees of permanence when exposed to high temperatures, either separately or combined. Neither have we any general conclusion to present concerning metallic salts, which likewise are not rare in veins, since these are also in the same way various in their origin and degree of permanence. There is besides a difficulty attaching to this branch of the subject arising from the interesting fact, that, in very many instances, metallic oxides and salts are derivative compounds from sulphurets and other primary combinations, and when this is very evidently the case, they are called epigene. This may be said to be even frequently the case with oxide of iron, carbonate of copper, and probably carbonate, phosphate, and other salts of lead.

Besides the metallic ores which impart to many veins their most striking, if not most constant characters, various earthy minerals lie in these repositories, and, as will afterwards appear, under certain definite relations to the enclosing rocks as well as to the included metals, and with a less distinct dependence on the local situation or mining district. These earthy substances are usually called the gangue, vein-stuff, or matrix of the ore. Generally they are crystallized, as quartz, fluor spar, calcareous spar, phosphate of lime, the sulphate and carbonate of barytes, strontites, &c.; sometimes appear massive, as quartz and several other minerals when the vein has no cavities in it; and sometimes the vein-stuff is entirely soft argillaceous matter, of different aspect in different mining districts. We are not aware that these soft kinds of vein-stuff have ever been analyzed, though probably some curious results might reward the labour. The Cornish mines would furnish many examples.

In some veins, masses of the neighbouring rocks are enclosed and penetrated to a great extent by little strings of the ore and spar, so as occasionally to be worth the trouble of working. The vein is said in this case to bear a rider. It, in fact, sometimes becomes under these circumstances a double vein: more rarely pebbles

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and other marks of watery action, are stated to occur in soft veins.

### Mode of Aggregation of the Ingredients.

In this respect there is a variety of appearances which deserve especial notice as indicating some of the conditions under which the vein was filled. In some cases, for instance, the whole breadth of the vein is occupied by one kind of substance, as lead ore, or quartz, or sulphate of barytes; in other instances, the metallic matter is interspersed in small masses through a general basis, as quartz; but, generally, the different substances which fill the vein are ranged in a definite order of succession from the sides of the vein toward the middle, in which, commonly, the metallic matter occurs in an irregular vertical table called a *rib of ore*. These variations are best observed in the proper veins, but are also to be noticed in the *nests* and detached masses of ore and vein-stuff which sometimes occur in the vicinity of the veins.

General  
idea of a  
mineral  
vein.

The ordinary notion of a mineral vein is well exemplified in some Derbyshire specimens, not rare in collections, which, when cut across, show in the middle masses or a continuous rib of galena, and on each side of this, to the extreme edges of the mass, (or narrow vein,) layers of fluor spar and carbonate of barytes in frequent alternation, all the materials being crystallized together without leaving any cavities, yet preserving their own character of structure.

Thus, in the diagram, pl. vii. fig. 11, *a* is the middle rib of galena, *b b*, *c c*, the alternating bands of barytic spar and fluor spar; *d d*, the masses of rock which enclose the vein, are called the walls or cheeks of the vein.

Supposed  
successive  
deposition  
of the sub-  
stances.

The contemplation of these specimens seldom fails to impress upon the mind an imperfect conviction that the several bands of mineral substances were deposited on the cheeks or walls of the vein in succession, the middle being filled last of all; and this theoretical notion has been illustrated by comparing a mineral vein to a narrow gallery whose walls were covered by many successive coats of plaster of different colour and composition. Werner adopted the notion of the unequal antiquity of the vertical layers of the vein so implicitly as to speak of the middle ribs as always of less antiquity. It is difficult to resist this impression, especially when, in addition to the circumstance of the succession of the laminae, we observe that these laminae are so crystallized as to turn their free terminations towards the centre of the vein, and in that direction to imprint the next layer with their own forms, just as crystals forming in a vessel shoot their points toward the part still remaining liquid, and in that direction are covered by the subsequently formed crystals. Very similar inferences are suggested by certain agates, and more distinctly by geodes in basalt, and the crystallized cavities in limestones, in the interior of shells, &c.; in which cases the hollow towards which the crystals pointed still remains.

Reasons  
against this  
notion.

Yet this first impression loses much of its force when, instead of confining ourselves to a cabinet specimen, we examine the whole extent of a mine; for here in the first place it is very often found that the regular succession of minerals from the side to the centre is a limited though repeated phenomenon; that the rib of ore is, of short horizontal, and sometimes still shorter vertical extent, diminishing to nothing, or diffused in small grains through the contiguous spars; that different

metals are found in the same vein at different depths and at distant points along its course; and that both the quantity of metal and the presence of spars are dependent on the hardness, and perhaps on some properties imparted by the chemical nature of the rocks which the vein divides. Instances of this will be given hereafter.

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The phenomena of crystallization before alluded to can hardly be thought to prove the successive introduction of the mineral laminae into the vein; though very probably they do demonstrate the order of crystallization of these substances.

Chemical  
reasons.

In some cases we observe indications that one kind of mineral has been formed round another as a nucleus; as for example, sulphuret of copper round icosædral iron pyrites in a part of Caldbeck fells, Cumberland, and more frequently in many places carbonate of copper and carbonate of lead round the sulphurets of those metals. It is very often the case that the metallic matter of the vein is collected into the middle and forms there a distinct tabular mass, called a rib of ore, more rarely it is disseminated in the gangue. Generally, only one kind of metal abounds in the same part of the vein, but the same vein may yield lead above and copper below, copper above and tin below, or lead in one place and copper in another. The observation is frequent that ore is collected into certain vertical portions of a vein which are worked above and below level, and between which little but vein-stuff is found in the horizontal drift. There is a vague notion amongst miners, that veins are most productive in the deep, and it is at least probable that they are less rich near the surface.

Werner insists on the fact, that certain associations of minerals can be traced in veins. He notices the concurrence of lead glance, and blende or calamine, and copper pyrites; of cobalt, copper, nickel, and native bismuth; of tin, wolfram, tungsten, molybdena, and arsenical pyrites; of topaz, fluor spar, apatite, schorl, mica, chlorite, and lithomarge; of brown ironstone, black ironstone, manganese, and heavy spar. He says where tin occurs, ores of silver, lead, and cobalt, heavy spar, calcareous spar, and gypsum are rarely found. Cinnabar and other ores of mercury scarcely ever occur with the ores of other metals, except iron ochre and iron pyrites.

Rolled and  
fragmented  
masses.

That fragmented masses of the neighbouring rocks should be found in mineral veins, cannot be thought surprising. It is a common occurrence in mining districts, both of primary and secondary rocks. Thus gneiss at Joachimsthal, clay slate in Cornwall, limestone in Cumberland, are included in the veins. A more remarkable case is that of *rolled masses* lying in the veins. Werner mentions a vein in Danielstollen at Joachimsthal, fourteen inches wide, which, at one hundred and eighty fathoms depth, was almost entirely composed of rolled pieces of gneiss, some of them nearly spherical. In the Stoll Kefier, near Riegelsdorf, a vein of cobalt was cut through by another vein of sand and rolled pieces. These examples seem satisfactory, but we must always be careful to discriminate between rolled pebbles and concretionary masses.

Mineral veins are usually distinguished by miners into several kinds, according to their general form and direction, because these circumstances are the most influential in the arrangement of their works. *Rake veins*, the most common and characteristic, may be considered to fill long, narrow fissures, which pass in a vertical or highly inclined direction downwards from the surface

General  
forms of  
veins.



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through a great thickness of the subjacent rocks, whatever these may be, and preserve nearly the same angle of inclination and the same linear direction through their whole course. *Pipe veins* are also highly inclined, and pass downwards in the same manner, but they rather resemble irregular chimneys than fissures, and are subject to great swellings and contractions of their diameter. They sometimes pass downwards along the surfaces, and in other cases penetrate through the substance of the strata. The mines in the neighbourhood of Ecton, in Staffordshire, are on pipe veins. Perhaps we may give the same name to the irregular cavity of copper ore, which forms the celebrated Parys mine in Anglesea, and to the iron mines of Dannemora, in Sweden. *Flat veins*, or *streaks*, as far as we are acquainted with them, seem hardly to deserve a special name, being only portions of rake veins which have been changed in their inclination, and made to pass for limited distances parallel to the beds. In the limestone districts of the North of England, this happens principally in connection with certain limestone beds. Williams has a title of *Gash veins* to express such as range for considerable lengths, like rake veins, but are wide at top, and grow narrower downwards, till they entirely vanish. This is a rare case; though Werner's opinion seems to be that many veins grow narrower downwards.

Strings

Perfect parallelism of the sides or walls of a rake vein, which is the most regular of all, is a rare phenomenon. Most commonly, indeed, there is a definite boundary to the mineral masses presented by the rocks on each side, but this is only on the great scale; and the operations of mining disclose to us innumerable cracks and fissures in these boundary walls, which, when filled by metallic or spongy matters, are called strings, and are frequently worth the labour of following even to great distances from the parent vein, if, indeed, we are entitled to use this hypothetical expression. The notion of miners generally appears to be, that these strings are to be viewed as *feeders* of the vein, and in proportion to their frequency in many instances, is the productiveness of the vein. In the accompanying diagram, pl. vii. fig. 12, the vein *r*, *r* is represented as sending out small branches or strings into the neighbouring rock. A rock thus penetrated by strings is sometimes said to be *ridered*, just as the masses which are often included in the vein, and the walls which bound it, are called *rider*. In many rocks these *ridered* parts are very greatly altered from their original state.

It sometimes happens that, in passing through rocks of various hardness, as limestone, shale, &c. the veins turn flat for a short distance on the hardest and most connected beds. (as, for example, on the Tyne bottom limestone of Cumberland,) and afterwards continue their course. These flat parts usually send off strings into the limestone, which may thus be *ridered* to a considerable distance.

Dissemination  
of veins,  
&c.

Sometimes the mineral is disseminated through the parts of the rock adjoining a vein, or collected in small nests and other closed cavities. This happens not only in the Cornish mines, in killas and granite, but in those in the mountain limestone tracts of the North of England, and even in magnesian limestone. Generally speaking, we may be sure that this metallic impregnation is so related to the veins, that it is an effect of the same agent. Whatever filled the veins, also transferred to small distances from them some of their constituent minerals. Certain metals and ores are more liable than others to

this lateral diffusion. Native silver, silver glance, red silver ore, native copper, tin ore, iron pyrites, and red iron ochre, are specially noted by Werner as occurring in this way. He says, copper ore, pyrites, and lead glance seldom exhibit this effect. The assertion may be disputed as to galena, which is found as well as blende, and bitumen, and calc spar, and quartz, in closed cavities of shells, in mountain limestone, and in other strata.

The dissemination of tin ores through some of the rocks of Cornwall, is noticed by Mr. Hawkins, under the title of Tin-floors. (*Geol. Soc. of Cornwall Trans. vol. ii.*) He observes, that the whole tenement of Botallack is said to be full of tin floors. At Zinnwald, mineral beds or floors have long been the object of mining adventure. There granite alternates with the tin floors, which consist of quartz and mica, with tin ore, fluor spar, and wolfram, quartz and mica with tin ore, &c. At Breitenbrunn a floor of this kind has been very extensively worked in a gneiss rock.

Tin floors,  
stockworks,  
&c.

The stockwork of the German miners is to be considered as a mass of rock impregnated with metallic matters, in numerous small veins, which come together irregularly, so as to make particular parts extremely rich. The working of such mineral repositories is directed by quite other principles than those which serve for straight veins of definite magnitude. The stockwork is generally opened like a vast quarry, and the excavations are prosecuted irregularly in the most favourable directions. Perhaps the copper mine of Parys mountain in Anglesea, the iron mine of Dannemora in Sweden, the tin ore mine of Geyer in Saxony, are examples of immense stockworks. Werner, however, appears to have considered the stockwork as peculiar to tin ores.

#### Relations of Veins to each other.

The influence which veins exert on each other may be in some measure ascertained by an examination of the phenomena at the points where they come into contact or cross each other. At these points it is very often found that the quantity of ore is suddenly increased to a large amount, and for some distance, either in one or both of the veins. Many veins are productive only near such points, or yield there peculiar ores and minerals. This does not depend upon the enlargement of the vein merely, but is one of many facts which appear to indicate the agency of certain electric attractions in the disposition of the materials of mineral veins. We have heard miners say, that in certain cases neighbouring veins are subject to a kind of reciprocity, so that they are not both productive in the same ground, but where one is rich the other is poor; but this cannot be established without a very large collection of instances carefully observed.

The intersections of veins likewise furnish us with another well-ascertained class of facts, which throw light on the relative epochs of their production, independent of the evidence on this subject furnished by the rocks which they divide. When two veins cross, it almost invariably happens that one of these cuts is continued right through the other, as a wall is sometimes continuous through another wall of brick from top to bottom. Thus, a vein of copper ore may cross and cut through a vein of tin ore, a vein of lead ore may cut through a vein of copper ore, and all these be cut through by some other sparry vein or porphyry dyke. It is supposed, by almost every writer on the subject, that the relative an-



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tiquity of the veins which thus intersect one another may be immediately determined; and that in every case the vein which is cut through is the oldest of the two. Werner took this as the basis of his classification of veins, and most practical as well as theoretical miners agree in his views; but they are nevertheless controverted upon various grounds, and as the question is of great interest, it will be useful to present a short connected view of the facts bearing upon it.

We cannot make a step in this argument, except upon the admission that the veins are posterior to the rock which encloses them; in other words, that the space in which the mineral masses of a vein lie, once existed as a fissure in the rocks, and was subsequently filled up by the accumulation of the sparry and metallic matters. This is generally supposed by authors to be a self-evident proposition. It is equally allowed by the Wernerian and Huttonian hypotheses; and practical miners can with difficulty be made to understand that any doubt has been entertained on what seems to them so plain a truth.

Phenomena  
in Cornwall  
considered.

But the embarrassing phenomena of the granitic and mineral veins in Cornwall have created amongst some of the Geologists of that district a strong suspicion, that veins are not to be pronounced of different antiquity on account of the circumstances of their intersection, nor to be considered as filling fissures at all; but that the veins and the rocks which enclose them are of the same origin. Even the common fact of veins passing through slate into granite, does not appear to them subversive of their views, which would reduce to one epoch and one origin the most dissimilar chemical and mechanical phenomena. This insulated opinion has been generally neglected, as opposed to the actual state of knowledge and inference on the subject, but as it undoubtedly contains at least a portion of truth, we shall trace a few of the circumstances on which it is founded. Those who favour the opinion in question, must not be surprised at our omitting altogether what may perhaps appear to them the strongest argument of the whole, *viz.* the mechanical difficulties attending the generally received view, that veins were originally fissures of the rocks, because these difficulties have been in some cases surmounted, and in the rest are certainly more than balanced by others of a different kind affecting the Cornish theory. It is, besides, no argument for one theory that another is beset by difficulties which are left unexplained in both.

In the  
neighbour-  
hood of a  
vein.

1. It is a general fact, that the walls of a vein partake in some degree of its characters, and that effects, apparently depending on the vein, propagate themselves into the neighbouring rocks. Thus the walls become more indurated, more crystalline, and for considerable distances are filled with the matters of the vein; and even the very substance of the rocks is impregnated with mineral combinations. In a Country where the veins are numerous, large masses of the rocks may in this way be *ridered*, as it is termed in the North of England; and if such a gradation of characters could be relied on as proof of contemporaneity of origin, this may in a few cases lead to the conclusion, that the veins and rocks are coeval.

But what is the true conclusion on this point? Is it not that these effects are locally related to the veins, because they are a consequence of their influence, or rather of the agency which occasioned them? That the *riding* of the neighbouring rocks is coeval with the production of the vein may be allowed; but because these rocks are clearly defined from the veins, and fragments

of them are enclosed in the veins, and the mineralizing influence which they have suffered obviously depends on the influence of the veins, we cannot hesitate to admit that these latter are of separate and subsequent origin. These facts are similar to what occur in other mining districts, where the stratification and consecutive depositions of the rocks divided by veins is perfectly evident, and where, therefore, contemporaneity of the veins is impossible.

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2. It is found, that when veins divide different sorts of killas or other rocks, that their contents vary in some inconstant manner, according to the nature of the rocks; and, therefore, it has been sometimes argued, that the production of the one is dependent on the other. The most usual notion on this subject is, that the veins may be viewed as secretions from the rocks; and by some this is supposed to have happened after the production of fissures; by others, by a mere internal separation of the parts of the mingled metallic and earthy mass.

In different  
rocks.

This notion of the slow separation of the ingredients of rocks is in accordance with the principles and facts of Chemistry, and must be often appealed to, if we would explain by *true causes* the phenomena of mineral veins; but with respect to the question before us it is indecisive, and may with equal propriety be applied to veins of fissures and veins of segregation. The same electric attractions between certain minerals in veins, and certain rocks about them, obtain in the secondary strata, as in the slates and granites of Cornwall; but if the preexistence of fissures in the former is certain, why shall we deny it in the latter?

3. There are combinations of minerals in masses of various figure, which, upon very good grounds, are admitted to be contemporaneous with the rocks in which they lie; and if we choose to call by the name of veins all such distinct combinations of minerals, these certainly are contemporaneous veins. When in granite, greenstone, &c., we find particular portions either linear, tabular, globular, or in any other figure which have a different proportion of ingredients from the other parts, and in consequence become conspicuous and distinct, except at the edges, which graduate without any sign of fissure into the ordinary mass of the rock; these may certainly be pronounced contemporaneous veins, and they have been produced by a process of secretion or segregation during the crystallization of the rock. These cases are perfectly distinct, and by contrast place in still more striking light the true relative age of veins of fissures.

Contem-  
poraneous  
veins.

In some instances veins of calcareous spar or other minerals lie *wholly included* in limestone masses, and these are properly called veins of segregation, but they are *not contemporaneous veins*, for they have clearly been fissures filled at some period since the consolidation of the rock, and the proof is, that shells, corals, &c., are split and sometimes displaced by these sparry veins, which undoubtedly occupy cracks left by the shrinking of the rock in the process of consolidation.

Upon the whole then, allowing every just latitude to the doctrine of contemporaneous veins, we must admit that the greater number of veins are posterior to the rocks which enclose them.

This granted, we may return to the intersections of veins. The most simple case is when two straight veins cross without any change of direction, or any lateral displacement; and the order of effects appears to be the production of a fissure, and the filling of this by

Intersection  
of veins.

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a vein, which was afterwards broken through by another fissure, and this, in its turn, received another mineral vein. It seems difficult to doubt the truth of this explanation; for if the vein which cuts through the other be subsequent to the fissure in which itself lies, it must also be subsequent to the vein which that fissure divides. The occasional complication of the problem by the number of intersections does not at all change its nature.

Appear-  
ances at the  
crossing.

There are, however, two things to be attended to, which require further consideration. It is sometimes observed, that the vein which upon this theory is the oldest, suffers a particular kind of accident at its junction with the other. It is divided into several branches on one or both sides of the cross veins, and these branches enclose portions of the neighbouring rocks. There is some difficulty in this case however it be considered, and we must demand more exact accounts than are usually met with of these facts before attempting to reason upon them. The coincidence of this splitting of a vein with the crossing of another vein, may often be only accidental; for such splitting frequently occurs in a wide vein, far from any cross course.

The fissures which have received the mineral veins are in most cases accompanied by slips or dislocations of the strata in a vertical direction, and the veins are of course subject to the same accidents of displacement. When two veins cross, and both are vertical, the lines of bearing of the two portions of the displaced vein must remain coincident after the fracture; if the divided vein be not vertical, its separated portions will have their lines of direction parallel, but not coincident; and in any horizontal plane they will *appear* to have sustained a lateral movement. Thus in the diagram, pl. vii. fig. 13, the cross vein *a* and the divided vein *b* are both vertical, but the divided vein *c* is inclined in the direction of the arrows, and its *apparent* lateral displacement is really due to a vertical movement. If two divided veins are inclined in opposite directions, and be dislocated by the same cross vein, they will appear to have moved laterally in opposite directions, as *c* and *d*.

Were we to include the cases of the inclined cross veins, and also those where the inclination of these veins varies both in amount and direction, the results would become too complicated for explanation without mathematical symbols; and we must, besides, remember that the displacement of the strata is really very seldom in a vertical direction, but generally accomplished by an angular movement from some fixed point, or round a virtual centre. We must, therefore, be very slow to admit the difficulty of the problem of the displacement of the solid masses of the earth as an argument against the received opinions concerning mineral veins, for this principally depends on the want of precise and sufficient data.

Several remarkable cases which occur in the mines of Cornwall have been simply explained by Mr. Lonsdale, and there can be no doubt that the application of the principles of solid geometry to other complicated phenomena of that interesting region will gradually remove much of the mystery which has been supposed to hang over them.

#### *Geographical relations of Veins.*

Though, properly speaking, there is no real connection between mineral veins and the external physical configuration of the earth, yet, as this configuration is con-

nected with peculiarities of internal structure, it is generally found, as Werner long ago indicated, that mining districts are almost entirely confined to the vicinity of mountains or elevated land, because in those situations the rocks were most dislocated by slips, and divided by fissures at the period of their elevation. It is not the absolute height of the ground, but the circumstance of its having been much exposed to subterranean convulsion that determines the prevalence of mineral veins. The rich mines of Cornwall are in comparatively low situations, but they are all in the vicinity of erupted and elevated rocks.

There appears to be no limit either of height above or depth below the sea, which defines the productiveness of veins, though in some Countries the higher, and in others the lower situations are most favourable.

It is sometimes found that the contents of a vein vary with the depth, without any particular geological conditions; as for instance in Cornwall copper is prevalent in the mines at greater depths than tin, and in the slate tract of Cumberland veins which bear lead near the surface yield copper in the deep. In other cases there appears a peculiar determination of the metallic ingredients to particular situations. The mines about Ecton yield copper; those of Derbyshire generally lead; in the Pennine chain the veins generally yield lead, but toward the Eastern and Western limits of the district copper becomes less uncommon.

The length of a vein or fissure is perhaps hardly in any case certainly known; because when it ceases to be worth working, it is for all the ordinary purposes of mining said to be dying out, or cut out, or ended. The richest veins are productive for limited lengths, but the fissures which they fill may be, and are often extended far beyond the spaces occupied by metallic impregnations. Some of them are known to extend, and to be productive for many miles in the Harz, in Cornwall, and in the North of England. The width of veins is various, in different veins, but generally nearly constant in the same vein. A width of twenty feet is very unusual; most veins are less than six feet wide.

There is a peculiar geographical relation of veins which is very difficult to understand, but which is so general that it may eventually be of the greatest value in correcting and perfecting our theories concerning them. This is the general *direction* of the veins. The most general direction of the great dykes and faults in the North of England, may perhaps be defined to be nearly East and West. But this is much more certainly true with respect to the mineral veins of the limestone districts of Weardale, Allendale, Alston Moor, and all the mining districts of Yorkshire; and it is equally recognised in the primary tracts of Cumberland, Westmoreland, and Lancashire. This is so general a fact, that the East and West veins are called right running veins; while the few which range more nearly North and South are called cross courses. These latter are seldom rich in metal; they often cut through and shift the right running veins laterally, as both of them shift the strata vertically. There is often to be observed a sort of compensation in the dislocating effects of veins. In Weardale most of the veins throw up to the North, while the parallel courses in Allendale and Alston Moor throw up to the South. The lead veins of Flintshire and Cardiganshire have the same East and West direction, and so have those of Mexico.

The lodes and veins of Cornwall are most generally

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East and West veins, or nearly so; and these, according to Mr. Carne's (*Trans. of Geol. Society of Cornwall*) excellent Memoir, the *oldest veins* in that district, being traversed by the oblique veins and by the cross courses elvans and flukans. But not all the East and West lodes are of the same age, the tin being older than the copper; neither are all the East and West tin veins of one age, for those that underlie to the North, are generally traversed by them that underlie Southwards. These curious generalizations are not to be overthrown by particular discordances; their value may one day more fully appear, and they are certainly supported by analogous though less varied occurrences in other Countries.

The general order of their dates may be thus expressed.

1. Oldest, East and West, tin veins underlying to the North.
2. East and West, tin veins underlying to the South.
3. East and West, copper veins generally East 10° South.
4. Oblique or *contra* copper veins, generally East 30° to 45° South.
5. Cross courses not metalliferous, North and South.
6. Copper lodes of more recent date and lead veins.
7. Cross flukans or clay dykes nearly North and South.
8. Slides in all directions, but generally East and West.

The porphyritic and other dykes called elvan courses, are very generally divided by the veins, and seem to be of greater antiquity.

Werner has observed this geographical relation of mineral veins, and states the two following cases. In the mining district of Freyberg are two classes of veins very different from one another. One of these classes consists of veins which run from North to South; the veins of this contain lead glance, black blende, iron, copper, and arsenic pyrites, quartz, and brown spar. This is the oldest vein formation. The second class of veins which always traverse the former, and are never crossed by them, contains lead glance, radiated pyrites, heavy spar, fluor spar, and quartz; they stretch between the sixth and ninth hours of the mining compass (East to South-East.)

The mining district of Ehrenfriedesdorf, contains veins of tin and silver glance. The tin veins are always traversed by the silver, the direction of the first is between the sixth and ninth hour, (East and South-East,) that of the last from the ninth to the third hour. (South-East, South, South-West.)

There is observed in some mining districts another remarkable relation of metalliferous veins to geographical lines. Though in the North of England, the most frequent direction of the *veins* be East and West, the *mining districts* seem rather to be ranged in lines from North to South. The nature of this relation will be more easily understood if we add that both in Cornwall and in Cardiganshire, where the veins are also most frequently East and West, Mr. J. Taylor has observed lines of greater productiveness ranging nearly North and South, across the bearing of the veins. These curious notices suggest the inquiry whether the lines of productiveness are dependent on any principal axis of dislocation or on the occurrence of cross courses. The former case seems to be vaguely indicated by the phenomena in the North of England; perhaps the latter may be more applicable to Cornwall.

### Connection of Fissures and main Joints.

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The remarks on the joints of rocks in p. 543, 544, may be referred to as sufficient to show the importance of studying their direction in connection with that of the fissures of mineral veins. It is certain that in the limestone dales of the North of England, mineral veins are sometimes directed along the master joints of the rocks, also that in the slate tracts, veins and dislocations range along the cleavage planes of the slates. (Craven.) Dr. Boase has noticed the same thing in the slate tract in Cornwall, and such observations will doubtless be multiplied. Mechanical considerations might have led us to anticipate this result; for the main joints and cleavage planes would often be the lines of least resistance and yield more easily than other parts to any eruptive or depressing force applied to the planes of stratification. The direction of the master joints is certainly definite over large tracts of country, and if we should find eventually that mineral veins have commonly taken the same course, their regularity will no longer be an argument against, but an additional evidence for the vertical movement of the masses.

### Relation of Mineral Veins to the Rocks which they enclose.

The relation of mineral veins to the rocks which enclose them offers a wide field of inquiry, which has been much studied, and yet is very little understood. It is difficult to distinguish clearly between the *accidental* and the *necessary* association of the phenomena of veins and rock masses; it is perhaps hardly possible at present to form a satisfactory opinion as to the amount of effects produced by causes acting from distant centres of force. We are in ignorance as to the subterranean operations of electrical and calorific agents still constantly going on; and to these theoretical difficulties must be added the unconquerable impediments to accurate and varied observation of the facts on which inferences are to be founded. Minute analogies of the relation of veins to the adjacent rocks would therefore at present be very unsatisfactory and hypothetical, and we must be content with the results which may be gathered from wide and general comparisons of phenomena on the grand scale. We shall confine the inquiry to metalliferous veins.

### 1. Relation to the different kinds of Rocks.

Considered as to their chemical nature, rocks may be classed as calcareous, argillaceous, siliceous, and mixed; as to their mineralogical characters, as uniform, or varied, granular, compact, or crystallized; as to their origin, aqueous, igneous, or pyrohydrogenous. Metalliferous veins occur more or less frequently in every one of these classes of rocks. In limestone, in argillaceous slate and shale, in quartz and sandstone rocks, and in rocks of mingled ingredients; in uniform slates, and fragmentary millstone grit, in granular sandstone, compact limestone, and crystallized limestone and granite; in sedimentary grits and shales, in pyrogenous porphyries, basalts, and metamorphic conglomerates. The existence of mineral veins in a rock is therefore wholly independent of the particular chemical and mineralogical nature and proximate origin of that rock; nor, when due allowance is made for the relative prevalence of the different kinds

Directions  
of veins of  
different  
antiquity.

Another  
geographical  
relation.

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of rocks, does there appear any reason to admit that, any preference or more frequent occurrence of metalliferous veins in rocks of particular kinds can be traced, *except in particular districts.*

Veins of  
certain  
metals.

There yet remains the inquiry whether certain metals are specially associated with or related to particular sorts of rocks. In order to answer this question satisfactorily, we must not content ourselves with instances such as tin veins and mercury veins, which occur in so few localities as to be rather dependent on their geographical position than on their geological repositories, but must cite veins of lead and copper, and disseminated ores of iron and manganese. Hardly any substance is more abundant in the mineral kingdom than iron pyrites: it occurs both in veins and disseminated crystals or concretions; and, in one or other of these states, it is associated with almost every known rock. It occurs disseminated in limestone of various kinds, as primary limestone, carboniferous limestone, and chalk; in clay slates, shales, and clays; in greenstone, amygdaloid, and basalt. Veins containing iron pyrites traverse rocks of as great diversity. Copper pyrites is not disseminated through so many rocks as iron pyrites, but it occurs in veins which traverse limestone, sandstone, and shale, clay slate, mica schist, granite, &c. Ores of manganese are also very generally diffused through rocks of very different kinds. The converse is true. In one and the same kind of rock occur veins of copper, lead, silver, and tin.

Affinities of  
metals to  
certain  
rocks

There are some metalliferous veins which traverse different sorts of rocks, and give us an opportunity of ascertaining whether any differences in the contents of the veins correspond with the variations of the rocks. The tin veins of Cornwall sometimes pass through clay slate and granite; they produce ores in both. "A vein that has been productive of copper ore in the clay slate, passing into the granite, becomes richer, or, what is more remarkable, furnishes ores of the same metal differently mineralized. If we pursue it further into the granite, the produce of metal is frequently found to diminish. A change of ground is looked upon by miners as affording reason to expect an alteration for better or worse." Taylor, *Report on Veins*

In Silesia.

Remarkable instances of this relation are given by Von Dechen (De la Beche, *German Trans.* 594.) The numerous veins which cross the steeply inclined strata of greywacke in the Liegen district, are metalliferous in narrow bands *parallel* to the inclined beds of greywacke. The veins of the Kupferberg, in Silesia, bear ore only in the hornblende schist, and are impoverished in mica schist. At Joachimsthal the mica schist is traversed by quartzose porphyry in veins, which, as well as the contiguous rock, hold pyrites. The rothegang of Elias consists in mica slate of loun, and holds only uranite; where it runs between mica schist, and a porphyry vein, and where it traverses the latter, its substance is a red hornstone, and it bears vitreous silver, native silver, arsenical-kobalt, bismuth glance, kupfernickel, arsenic, and bismuth; but red silver, elsewhere abundant, is entirely wanting.

In North of  
England

In the lead veins of the North of England, which are situated in the carboniferous limestone tract, a singular dependence is observed between the contents of the vein and the nature of the adjacent rock. The vein divides limestones, sandstones, and shales, and these are brought variously into opposition by the dislocations which accompany almost all the veins. The vein is sometimes productive of lead ore under every case of opposition on

rocks. Where limestone, or schist, or solid sandstone forms the walls, its productiveness is at the maximum, but generally it is contracted in breadth and impoverished in its metallic contents, wherever it is included between walls of shale, and even where only one side is occupied by shale, the same effect is frequently observed. It would appear that the impoverishing influence of the shale is referrible to mechanical causes. In the same way as the shales in a coal-pit swell out from the undisturbed parts to fill the artificial vacuities, so we may conceive them to have done into the natural fissure; this will account for the contraction of the vein. In the process of crystallization, to which all the contents of a vein are subject, it seems conformable to analogy to suppose, that the permanent walls of limestone and gritstone would permit a more early growth of sparry and metallic crystals, than the crumbling edges of shale; a supposition, perhaps, confirmed by the occasional mixture of shale in the sparry mass of a vein, where it is "nipped," as the miners say, in beds of shale. There may be something in this due to electrical affinities, and we may perhaps apply the same supposition to the cases in Cornwall and Germany, quoted above, where the deposition of the ores is influenced by change of ground.

From some or all of these causes it happens in the North of England that *certain* limestones are very much more productive than the others; in different mining districts, *different* limestones are thus favourably distinguished, but in the country of Alston Moor, Teesdale, and Swaldale, the uppermost thick limestone is by far the most rich in lead. To prove this, and at the same time to record a valuable fact, we may copy from Mr. J. Taylor's Report on Mineral Veins (*Reports of the British Association*, vol. ii.) the following statement of the quantities of lead ore actually extracted from the several sites of bearing beds in Alston Moor in the year 1822, according to the account of Mr. Dickenson; we have added the thickness of the several beds.

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lead ore,  
from differ-  
ent beds of  
limestone.

Limestone beds:—		Thickness in yards.	
Great limestone	.....	21	20.827
Little limestone	.....	2	287
Four fathom limestone	....	8	91
Scar limestone	.....	10	90
Fine bottom limestone	... ..	8	393
		—————21.688	

Gritstone beds:—		
High slate sill	.....	8 107
Low slate sill	.....	7 289
Firestone	.....	11 262
Pattinson's sill	.....	4 259
High coal sill	.....	4 327
Low coal sill	.....	3 154
Tuft	.....	3 306
Quarry hazel	.....	10 44
Nattrass gill hazel	.....	6 21
Six fathom hazel	.....	12 576
Slaty hazel	.....	4 18
Hazel under scar limestone	.....	4 2
		————— 2.365

Whole produce of the mines }  
of the manor, 1822. } 24.053 bings.

Upon the whole there is no sufficient evidence to show that the local *production* of metallic substances is in any special manner dependent upon the chemical or mineralogical composition, or the circumstances of the forma-

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tion of the adjacent rocks, though in some particular, and, indeed, many instances, we observe the *aggregation* of the substances in the vein to have been decidedly influenced by some peculiar conditions of the including rocks.

### *Walls of a Vein.*

Alteration  
of sub-  
stance.

The walls or cheeks which form the more or less definite boundaries of the vein present several facts worthy of notice. In some instances they are highly indurated, as if in contact with trap rocks, (North of England,) very often fissured, so as to break parallel to the vein. In others it seems as if certain sorts of rock (as clay slate, both in Cornwall and Germany) were greatly softened, and even converted to clay, along one or both sides of a vein. Werner mentions the decomposition of felspathic and hornblendic rocks for a fathom from the vein. We have also witnessed the fact of limestone, usually a blue or grey crinoidal rock, burnt, as the miners term it, that is converted to a brown granular crystalline rock. (Teesdale.) Another remarkable effect in the walls is the production of slickenside, so long known in the mines of Derbyshire, which are situated in limestone, and filled with fluoric and barytic shales and yield lead; in those of Cornwall, which are in kilas, and with a matrix of quartz, and yield copper; in the magnesian limestone of Yorkshire, where copper or lead lines the limestone cheeks; and in the faults of the coal system of Yorkshire, where neither spar nor metallic matters occur. These and many other occurrences of rubbed surfaces along planes of fissures speak a plain language, and prove to the fullest conviction, the mechanical movement of the sides of the fissure upon one another, or upon the contained substances. The groovings of the surfaces, thus produced by rubbing, indicate, of course, the line of the movement; the circumstance that the polished faces are partially covered by lead ore, copper ore, &c., as the nature of the vein is, proves, moreover, that the movement was, in such cases, posterior to the introduction of the whole or a part of the mineral impregnation, so that the same fissure has been, in such cases, the plane of more than one convulsive movement. We may, perhaps, eventually draw from examinations of this phenomenon, in connection with and apart from mineral veins, some decisive results as to the time and other circumstances connected with the movements of the masses. How can the Geologists of Cornwall doubt the reality of those angular movements, which have left such clear evidence as the fine slickensides of some of their veins of fissures? We think with Von Dechen (*German Transl of De la Beche's Manual*) that any other than the received explanation adopted above is impossible.

### *2. Relation to the different Ages of Rocks.*

This relation  
evident.

There can be no doubt of the fact that the local occurrence of metallic veins is in a very great degree dependent on the relative antiquity of the rocks in the district. It is in the primary, transition, and carboniferous strata, and in the igneous rocks associated with them, that all the veins in Great Britain are worked. In a few instances veins of small value, producing lead and copper, pass through the magnesian limestone, but not a single example is known of a true metallic vein in the oolitic, cretaceous, or tertiary strata. The connection of metallic veins with the older rocks is not an accidentu-

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coincidence, but a constantly recurring phenomenon, and the absence of such veins from the newer strata in England cannot be resolved into any circumstances of the geographical position of these strata; for both around the metalliferous slates of Cumberland and limestones of Derbyshire, the new red sandstone formation is extensively spread in contact, and yet not one lead or copper vein occurs in it. Any one who should confine his attention to the British Isles might infer that the causes of the production of mineral veins had been almost wholly inactive ever since the carboniferous epoch; and as a general expression, this may apply to the Continent of Europe, though both in the Pyrenees, and around the central granitic tract of France, metalliferous veins, apparently originating in these rocks, traverse strata of the oolitic and cretaceous systems.

It must here be remarked, that both in Great Britain and throughout Europe rock veins and basaltic dykes are in the same manner abundant in the primary and rare in the secondary and tertiary strata. This is one of many general analogies tending to substantiate the opinion previously advanced upon more specific points of agreement, that rock veins and dykes, and metalliferous veins, form two parallel series of igneous products developed during the same geological periods, by the same general causes, acting under different circumstances upon different materials. From all our previous investigations, we have been led to the conclusion, that in the earlier geological periods, the chemical effects of heat and mechanical effects of heat were more conspicuously exerted; and if to this we join the consideration that all the disruptions by which igneous rocks were put in contact with secondary and tertiary strata, must have been experienced by the older strata, from beneath which the expansive force originated, we shall be able to perceive why the primary are so universally and the secondary and tertiary strata so partially enriched with mineral treasures and diversified by rock dykes.

As an example of veins of more recent date, we may quote Von Dechen's notice of the veins of Joachimsthal. In this case the dykes of basalt and wacke which divide the mica slate are themselves cut through by the mineral veins. These dykes are variously connected with great overlying masses of basalt which break into the brown coal formation. It is therefore evident that the silver, arsenic, and kobalt ores have been thrown into the veins at a later epoch than that of the brown coal tertiary deposit at the foot of the Bohemian Erzgebirge.

Werner appears to have been strongly impressed with the belief, conformable to his general theory, that vein formations might be classed as to their ages by mere examination of their component substances. When veins, even in distant countries, contain the *same* ores and vein stones, and when these are arranged in the same determinate order, he concludes that they belong to one and the same general formation. Illogical and hazardous generalizations are frequent among practical men, and are too often introduced among the valuable facts recorded as a basis for Werner's Theory of Veins. A prudent reasoner would scarcely venture to trust an inference for time upon data which indicate only definite *chemical action*, even in a limited district, and it must be with some distrust that we can admit Werner's eight principal vein formations in the mining field of Freyberg; because he does not state *expressly* that his inferences concerning their relative antiquity were based on observations of their intersections.

The same  
relation ob-  
tains in  
rock dykes.Very mo-  
dern veins.

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eight sys-  
tems.

The following abstract of the account of these eight systems of veins will show the kind of description which should always be given of mineral veins.

The first and oldest produces abundance of argentiferous lead glance. It consists of coarse granular lead glance with from one and a half to two and a half ounces of silver per quintal; common arsenical pyrites; black blende in large grains; common iron and hepatic pyrites; sometimes a little copper pyrites, and a little sparry ironstone. The veinstones are chiefly quartz; sometimes a little brown spar; rarely a little calc spar. These substances occur most generally in veins ranging from *North to South*.

The second yields lead very rich in silver. It contains lead glance large and small granular; black blende in small grains; iron and hepatic pyrites, and a little arsenical pyrites. In addition, dark red silver ore, brittle silver ore, white silver glance, plumose antimony ore. The veinstones chiefly quartz, with much brown spar and often calc spar. The veins range *South and South-West*.

The third yields lead glance with one ounce of silver per quintal, much iron pyrites, a little black blende, and red iron ochre. Veinstones quartz, sometimes with chlorite mixed and surrounded with clay. Veins range *North and South*.

The fourth yields lead glance with one-fourth to three-fourths of an ounce of silver per quintal, radiated pyrites, and sometimes brown blende. Veinstones heavy spar, fluor spar, a little quartz, and rarely calc spar. Veins range *East and West*. (To this system Werner boldly refers the veins of Derbyshire, the Harz, and also those of Gaskoff in Scania.)

The fifth consist of native silver, silver glance, and glance cobalt, sometimes with grey copper ore, lead glance rich in silver, fine grained brown blende, and sparry ironstone. Veinstones, heavy spar in a state of disintegration, and fluor spar. It always occurs in the *intersections* of the first and fourth systems. (North and South, and East and West.) It sometimes is found even in the middle of the Westerly veins.

The sixth contains native arsenic and light red silver ore; with a little orpiment, copper nickel, glance cobalt, native silver, lead glance, iron pyrites, and sparry ironstone. The veinstones are heavy spar, green fluor spar, calc spar, and a little brown spar. Occurs in the intersections of the fourth and fifth systems, or in the middle of veins.

The seventh is of red ironstone, with a little iron glance, quartz, and heavy spar. Occurs in the *upper parts* of veins.

The eighth and newest is of copper pyrites, mountain green, malachite, and red and brown iron ochre, with a little quartz and fluor spar.

### 3. Relation to the Local Centres of Igneous Action.

Our investigations lead directly to the inquiry, how far the geographical occurrence of metalliferous veins is connected, as that of rock dykes is known to be, with the eruption of igneous rocks and the movements of fluid masses within the Globe?

Satisfactory evidence on this subject can be obtained in two ways: 1. By comparing metalliferous and non-metalliferous districts of old strata in their geographical relation to igneous rocks and convulsions. 2. By comparing the relation to igneous agency of the locally metalliferous newer strata.

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The older rocks are not by any means universally stored with metalliferous veins any more than with rock dykes. Very large tracts in the slate rocks of Devonshire are nearly devoid of metals, but near the granitic masses of Cornwall they are abundantly supplied with veins. In the vast districts of Wales the slate rocks yield copper and lead chiefly along the Western borders of the Principality, where the local centres and axes of elevation are situated. Amid the Cumbrian Lakes, lead and copper veins adjoin the granitic, hypersthenic, and syenitic axis of Carrock, Skiddaw, High Pike, &c. They occur near the porphyries and traps of Helvellyn and Old Man, but the greater portion of the slates, far removed from the foci of disturbance, are devoid of mineral treasures.

In Scotland, metallic veins adjoin the granitic nucleus of Strontian.

The mining tracts of the Harz, the Erzgebirge, Hungary, Brittany, and other localities are convulsed by disruption and diversified by the intrusion of granitic and porphyritic rocks; the Ardennes mountains, which yield few veins, develop hardly any igneous rocks.

The carboniferous limestone tracts of Mendip, Derbyshire, and Flintshire, of Wharfedale, Swaledale, and Aldstone Moor, have been shaken to pieces by many convulsions, and they are very rich in lead, zinc, and calamine; but the greater part of the Yorkshire and Northumberland limestones, affected by only one or a few general elevations, are poor in metal.

The newer rocks are metalliferous only in the vicinity of the foci of their disturbance, as round the central granitic rocks of France, near the igneous masses of the Pyrenees and the Alps; in all which places, the metallic ores are so related to the igneous rocks that they occur only in a narrow zone at the junction of the igneous and the altered stratified rocks. (Observations of Dufrenoy, Von Buch, &c.)

As both these methods of comparison lead to one result we may venture to adopt it; and the more readily because, in preceding sections, we have found the geographical situation of mines to be related to the elevation of the ground, and the metalliferous strata often identical with those in which rock veins abound. Nevertheless we must not shut our eyes to some decided differences between the situations of dykes and veins. For instance, the Island of Arran is traversed by hundreds of dykes of basalt, porphyry, and pitchstone, but metallic veins are almost unknown there; Aldstone Moor is dissected like a map by veins of lead ore, but very few whin dykes occur there; on the contrary, in Northumberland and Durham whin dykes abound in the coal tracts where lead is hardly known. It is, besides, too remarkable a thing to be overlooked, that South of the Yorkshire Swale hardly a whin dyke or porphyry dyke is known through the metalliferous tracts of Derbyshire, Somersetshire, and Flintshire. This contrast is the more remarkable in the country about the sources of the Tyne and Tees, because there basalt has been erupted in vast quantity, and at its Eastern termination appears related to several dykes of great extent. This mass of basalt is traversed by the veins in the same manner as the limestone is, and we may, perhaps, hazard the speculation that under this tract of country lay at one time melted basalt, and at a subsequent time the metallic and mineral combinations which fill the veins. Will it be thought too great a stretch of fancy to attribute this change of the igneous materials erupted in the same

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Ch. III.In older  
rocks.In newer  
rocks.Conclu-  
sions on  
this subject.

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tract of country to movements in the internal nucleus of the Globe not isochronous with the rotatory velocity of the solid superficial crust?

### *Electricity of Veins.*

Mr. Fox's  
experi-  
ments.

The direction of electrical currents at small depths below the surface of the Earth, is a subject on which theory is at present silent, and which has only recently been proposed for observation. The observations of Mr. Fox in the mines of Cornwall and Devon and North Wales, are still the most important of the kind. Mr. Henwood is engaged in further inquiries. As far as appears at present, the interest attached to the solution of this question belongs more particularly to Electrical Science, and, perhaps, both chemical and thermal disturbances of equilibrium may be concerned in the effect. These currents may be due to local causes. Mr. Taylor very properly observes, (*Reports of the British Association*, vol. ii. p. 18.) that by the very act by which we gain access to a vein we lay it open to atmospheric action, and consequently to decomposition.

Chemical agency commences, and with it, very naturally, galvanic influences are excited. Veins containing ores little subject to decomposition have, he apprehends, been found to give little or no indication of this nature.

Mr. Fox appears to think that the direction and intensity of the currents which pass along the veins may be so related to the position and quantity of metallic matter, as to give reason to hope for some direct useful application of the results to the Art of Mining. But the novelty of Mr. Fox's experiments, and the connection of the currents with mineral veins, led some Geologists to adopt the very hasty conclusion, that the production of the veins was mainly owing to such currents. It is very probable that electrical currents have really been concerned in the distribution of metallic ores both in veins and rocks, for when is this agency absent from any great chemical phenomena? But to conclude, without any intermediate steps, because mineral veins are channels for electricity, that they have been produced by electricity, is the same thing as to ascribe to electrical currents the construction of the galvanic battery.

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## CHAPTER IV.

### GENERAL INVESTIGATIONS AND INFERENCES.

#### SECTION I.

#### *On the Consolidation and Alteration of Stratified Rocks.*

In a preceding section we have seen the effects produced by the Plutonic rocks upon the strata which they penetrate; effects which suggest to our minds so vivid an impression of the action of heat, that even in the absence of all other arguments from facts, we could not refuse to allow that those rocks had been local centres of heat. The independent evidence arising from the composition of the rocks satisfactorily confirms this inference, and permits us to apply it in circumstances when the actual proximity of igneous rocks cannot be ascertained. These effects seem to be reducible to several cases, depending on the degree of heat communicated, and the substances operated on.

Effects of  
Plutonic on  
stratified  
rocks.

1. The consolidation of stratified rocks is exemplified in the induration and contraction of shale, and in the development of new faces or joints in it, which sometimes meet one another rhomboidally, and sometimes follow the columnar relations of the adjoining basalt.

2. The partial fusion of some part of the substance of a rock, so as to conglutinate its grains, and solidify and harden the whole mass. Thus sandstone is converted to a granular quartz rock.

3. The complete fusion or vitrification of the rock; thus converting shale into Lydian stone and sandstone into a kind of jasper.

4. The complete fusion and consequent rearrangement of the particles into granular or crystalline forms, as in the instance of common chalk in Ireland, common limestone in Yorkshire, the Isle of Sky, and Carrara.

5. The generation of minerals not before existing in a distinct state in the substances affected. The production of pyrites, asbestos, anthracite, plumbago, garnet, &c.

along the contact of igneous and aqueous rocks, is a very characteristic and general effect which appears to result from the actual transfer of the metallic and other matter through the solid substance of the rock, in virtue of electric attractions which may be considered as imparted by the heat.

If Von Buch's notion of the impregnation of rocks with magnesia in the vicinity of augitic trap rocks should eventually be substantiated, it must be considered as a remarkable example of this electric transfer.

6. The sublimation of some portion of the neighbouring substances. Thus the charring of coal, the desulphuration and the debittumenization of shale, are very directly connected with the heating power of the igneous rock, but it is probable that some peculiar conditions were required for such effects in the submarine depths, where most of these operations were performed.

The almost universal coincidence of convulsive dislocation of the strata with eruptions of plutonic rocks, seems enough to prove their common dependence upon one pervading cause of internal movement. In the same manner as the modern earthquake precedes the eruption of lava, so the ancient convulsion preceded the injection of plutonic rocks. Also precisely as in the present day the earthquake shakes Countries far removed from volcanic centres, so in more ancient periods many tracts were convulsed but not filled, at least near the surface, with melted rocks. As far as at first appears, the common dependence of the two orders of effects upon one cause, is merely to the amount that the mechanical transference of melted rocks has been effected by the same internal pressure which dislocated the strata; whatever occasioned the pressure, and whatever was the cause of the fluidity of the rocks.

Relation of  
igneous  
rocks to  
convulsions

Various mechanical modes may be conceived, by which



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such pressure may have been occasioned, and various conditions assumed for the production of melted rocks, and these may be wholly distinct from one another; but the exhibition of these rocks along the lines of convulsion can only be ascribed to the same mechanical cause which produced the convulsion.

The chemical theory of volcanos, advocated in the preceding pages, assigns a single cause for the chemical phenomena, and for the disturbance of the external crust of the Earth; and the same simplicity is sought for in one modification of the theory of an internal heated nucleus; but it may possibly be more correct to assign separate causes for the production of these effects. Judging merely from their relative frequency and geographical extent, we might be led to assign much more extensive agencies to the production of convulsions than to the elevation of igneous rocks. The whole area of the dry land has been subject not only to general elevation but to partial convulsions, several times repeated under the same spots; but igneous rocks are less universally, though certainly very extensively diffused. This distinction, however, loses much of its force when we consider, first, that plutonic rocks become constantly more and more abundant in comparison to the number of convulsions as we descend towards the base of all the strata; secondly, that though the effects of convulsion might pass through all the strata to the surface, and thus relieve the inequality of pressure, the melted matter from below could seldom penetrate the narrow and confused and cold passages left among the fractured strata, to any great elevation; thirdly, that rocks of igneous origin do really underlie the whole series of strata.

General  
basis of ar-  
gument.

Upon the whole we may safely admit, that igneous rocks have been in a state of fusion beneath the strata, either simultaneously or successively, in all or nearly all parts of the Globe, and that the elevation of these has been always accompanied by convulsions. Instructed by the discovery of the effects of these rocks upon adjoining substances, we may now proceed to inquire into certain phenomena of much more extensive occurrence, but of nearly a similar character, and which appear due to the pervading action of heat upon stratified rocks since their deposition.

Ratio of the  
consolida-  
tion of  
strata

On reviewing the series of strata in relation to the degree of their consolidation, it is impossible not to perceive that this increases continually with the age of the rock; so that, taken as a group, the primary systems of gneiss and clay slate, with all their modifications, are far more consolidated than the other strata, while the tertiary strata are the least indurated of all. The same result is obtained by more minute comparisons of analogous rocks, the slates, shales, and limestones of the primary series, with the shales, and clays, and limestones, and marls of the secondary and tertiary strata. A plausible cause for this seems to offer itself in the greater pressure to which, it may be imagined, the lower strata have been subjected; but this is not sufficient to account for the whole effect of consolidation, and is directly negated by the numerous joints and fissures, which indicate lateral rather than vertical contraction of the strata. The lowest strata are, besides, not merely in a high state of consolidation; some of them, as primary limestone, display in a most decided manner that crystalline structure which results from heat; others, as clay slate, are fissured in such a way as is known to have been locally occasioned by the heat communicated from igneous rocks; others, as quartz rock, show clear proof of having under-

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gone, if not actual fusion, at least such an agglutination of the grains as can be produced by art in a furnace. The conclusion from all this is of great importance; for as these rocks are of almost universal occurrence below all the other strata, and their characters are not referable to the local proximity of igneous rocks, we are assured, taking into account the subjacent granitic rocks, of the almost universally pervading influence of subterranean heat.

It is impossible at present to point out exactly the amount of changes which have been produced on the primary strata by the general and continued communication of heat from below; because, with respect to some of them, it is difficult to feel very confident of the precise state in which they were deposited by water. With respect to gneiss, for example, which is in some cases almost identical with granite, in other cases approximates to sandstone, it is hard to say how much of its granitoid character is due to subsequent metamorphism; because we have no certain means of knowing the degree of movement to which its ingredients had been exposed in water. Yet when we consider the bedded and laminated character of this rock, and observe that its constituent minerals are mostly in a fragmentary state, and even when united into a dense rock, are not crystallized with regular external forms, we seem to understand that the rock has been solidified by a species of imperfect fusion at the edges of the constituent substances, which, carried to extreme, would have reconverted the whole to granite.

Alterations  
of primary  
strata.

Similar remarks apply to mica schist, which, on the one hand, varies to gneiss, and on the other to clay slate; and it is observable that the fusible mineral garnet, which is known to have been generated at moderate heats in contact with trap, is very generally intermixed with the laminae of gneiss and mica slate. (p. 562.)

Among clay slates of every degree of fineness of grain, the action of heat is chiefly evinced by the extreme condensation of the argillaceous substance; by the regularity of the system of fissures; by the interspersions of crystallized pyrites, hornblende, &c.; by the frequency of segregated quartz veins. Perhaps these latter occurrences may be due to local causes; but the systematic fissures and cleavage of slate is a general fact, which is most striking in the deeper parts of the deposit, and gradually vanishes upward. So long as the basis of the rock is very fine grained, the cleavage structure will pervade it, and even cross laminae of very coarse matter; but when the basis is altogether coarse, as in greywacke slate, the cleavage vanishes, and is only indicated by numerous fissures, dividing the rock into rhomboidal masses. In a given tract of country the planes of cleavage have one prevalent direction, and the system of fissures appears also definable in direction. The general horizontal direction of the cleavage planes in a part of the Cumbrian mountains is West North-West, which is exactly that of the great Craven fault. (*Geol. Trans. New Series, vol. iii.*)

Of clay  
slate.

It is usual and probably correct to consider the systematic fissures and cleavage of slate as a kind of crystalline structure on the largest scale; the angles of intersection seem, however, to be assignable only for very small distances, and they vary in different strata of slate. Something like polarity must perhaps be supposed to account for the constancy of the direction of cleavage.

It does not appear that the heat imparted to the primary strata has been always sufficient to destroy the



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organization of shells or even plants, for shells occur in the slates of Tintagel and in Snowdon, and lie between gneiss beds in the Pichtelgebirge and Erzgebirge, and are noticed by Von Buch in the dolomite near Lugano. A long continued and pervading rather than a very high heat seems best to account for the phenomena. In the neighbourhood of igneous rocks, indeed, the local changes are of rather a different description.

If we rise to the contemplation of the carboniferous system we shall be able to trace in the generally high state of induration of the sandstones, shales, and limestones, and in the frequency, systematic direction, and continuity of the joints, clear evidence of the action of heat. But yet we perceive that these effects of heat are not nearly to the same degree as those in the primary strata. A simple proof of this is afforded by the limestone of Teesdale which is a hard rock, but which, where it touches the basalt of that country, has been subjected to nearly the same change as that observed in primary limestone: it has become crystalline. The shales are also altered. The upper portions of the slate system in Shropshire and Radnorshire, where that system is immensely thick, show the same changes.

Decreasing  
effects of  
heat in  
newer  
strata.

The effects of general heat continually decrease among the superior strata of the saliferous, oolitic, and cretaceous systems, and seem almost wholly lost in the tertiary strata. It is chiefly to this graduated effect of heat that we may ascribe the distinctness of the rocks in different parts of the series. Thus to take the calcareous rocks, we have a gradually changing series proportioned to their antiquity, from crystalline primary limestone, through highly condensed carboniferous limestone, to compact lias, concretionary oolite, marly chalk, and lacustrine marls; among sedimentary deposits there is a series from gneiss through the hard sandstones associated with the carboniferous limestone to the sands of the oolites, chalk, and tertiaries; and another from cleavable slate, through jointed greywacke slate, hard coal shale, compact red marl, and clay of the oolite, chalk, and tertiaries. There is properly no sand, clay, or marl among the older strata; indurated shale, hard gritstone, and solid limestone are of rare occurrence among the younger.

It does not appear that the occurrence of ironstone, pyrites, gypsum, &c. in detached masses among the stratified rocks is to be considered as in any direct or exclusive manner due to the influence of heat, but rather to the ordinary forces of molecular electric attraction operating during or after the deposition of the mingled mass of matter. The spar veins in septaria have undoubtedly been filled since the concretion of the clay balls, and for the transfer of the calcareous or silicious matter we must appeal to the same processes which have filled the cavities of shells and many cracks in limestone rocks with the same materials. No doubt in these effects an elevation of temperature might modify and perhaps accelerate the results, but it would be ridiculous, at present, to adopt Dr. Hutton's notions on some of these subjects.

Effects of  
heat on the  
deposition  
of strata

The preceding examples show clearly the effect produced on strata by the action of heat since their deposition; there can be no doubt that the same powerful agency must, especially in the earlier eras of Geology, have greatly influenced the manner and circumstances of their deposition. On this subject, however, we have not at present much to record, and that little is wholly confined to the primary series of strata. There

is one leading fact often connected with the stratification of gneiss, mica schist, &c. and not seldom repeated in chlorite schist and clay slate, which seems wholly unexplained by the direct action of heat upon these strata. The contortions of the laminae of these rocks are very remarkable, and seem evidently coeval with their first formation, though in some instances Dr. Macculloch thinks they are most numerous where quartz veins penetrate the rock. These contortions may, perhaps, be understood by comparing them with some analogous cases in laminated sandstone, where the undulations and confusion of the laminae indicate agitation in the water. If we allow that the water in which gneiss and mica schist were formed, was heated to a great degree by contact with or proximity to the sources of subterranean heat, the agitations of the ebullient liquid might, possibly, give to the strata then forming under it the very peculiar character of minute and irregular undulations which so often belong to these ancient rocks.

Another thing apparently characteristic of the mode of deposition of the primary strata is the isolated condition of the limestones which interlaminate the schistose rocks. How different in this respect are the detached often lenticular primary limestones of Scotland, and even the transition limestone of Devonshire and Wales, from the regularly continuous calcareous beds of lias, oolite, and chalk! Is it not very probable, that some local efflux of gases or the influence of local centres of heating agency, have sometimes performed the same effects as coral animals, and determined to particular points the extremely limited decomposition of the ocean water which undoubtedly was the source of the limestone deposit?

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## SECTION 2.

*On Disturbances of the Strata.*

The introductory observations in p. 540 to 543 may serve as a foundation for the following inquiries into the effects and causes of subterranean convulsion; and the remarks in p. 571, 597, 619, 634, 657, 658 may be read in connection with the preceding section of chap. iv. and the whole of chap. iii. This great subject may be carefully considered in four divisions.

1. The geological periods of convulsion.
2. The direction of convulsive movements.
3. The effects of convulsions in altering the relations of land and water.
4. Effects on the deposition of strata and on organic life

*Geological Periods of Convulsion.*

In order that our statement of results on this important subject may be as much as possible free from objection, it will be convenient to begin by fixing what phenomena are to be taken as proof of the occurrence of convulsions, and what method is to be followed in assigning their place in the scale of geological epochs. When strata, originally level, or nearly so, have been raised to high angles of inclination; when beds, originally continuous, are found to be broken asunder, and their separated portions placed in new relations of position, one portion being raised or depressed, or both deranged; when layers, originally plane, are found to be bent into extraordinary curvatures; in all these cases the conclusion is imme-

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diate, that convulsions have happened in the very points where such phenomena occur. The only question which can arise, supposing the actual position of the rocks well ascertained, respects the certainty of our postulate of their former position. Persons who have read old books, but have not studied natural phenomena in this point of view, may be apt to suppose that, under particular circumstances, strata may be formed at high angles of original inclination. Those who have looked more narrowly into the matter, and have been instructed by Mr. Yates's observations on the positions assumed by earthy materials falling in air and in water, may be led to extend the judiciously limited inferences of this author to cases where they will not apply. For very limited areas, and in extremely troubled waters, the mountain torrents, or the surf of the ocean, tumultuous deposits of sand and pebbles happen, in which the laminae may be inclined at considerable angles, and cover one another confusedly. On this account it seems not unnecessary to reexamine the basis of our argument, and see whether it will bear the weighty superstructure we design to lay upon it.

Examina-  
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argument.

1. General experience assures us of the general fact, that it is a characteristic effect of agitated water to deposit what sediment falls slowly from it in the form of strata whose upper surfaces continually tend to become horizontal. This is seen in inundations from a river, in shallow and ruffled lakes, and within the low-water margin of the sea. The form of the bottom influences the horizontality of the upper surfaces of the deposits in such a way, that where the bottom is like a pit, the stratified masses above are hollow on the faces; but these effects of the original inequality are rapidly obliterated by successive coats of sediment, all becoming more and more nearly horizontal.

2. In perfectly tranquil water, through which any fine sediment is equally diffused, the depth to which this will cover any part of the bed depends on the depth of the supernatant water, and on the *angle of rest in water* of that kind of sediment. The *angle of rest in air* for earthy substances is about  $45^\circ$ .

3. If a river bring sediment into agitated water, this will deposit it in strata tending to become horizontal, but with a constant dependence upon the point where the river enters, such that, the quantity of sediment being there always accumulating, a general conical slope therefrom in all directions will modify the horizontality of the strata.

4. If a river bring sediment into calm water, or into water suddenly deepening, so that all its lower parts may be considered as calm, the conical slopes from the point where the river enters will be much more abrupt than in the former case, in a certain proportion to the calmness and depth of the water. This Mr. Yates finds to be the case in the deep lakes which receive the abundant sediment of the boisterous torrents of the Alps; and, in consequence, we are furnished with a key which will ultimately open many curious results in the arrangement of sedimentary deposits. (See p. 707.)

On considering these cases with reference to stratified rocks, it is evident that instances coming within the class of conical deposits radiating round a point can only be of very limited occurrence, not likely to affect a general argument, and are, in fact, almost unknown. The estuary deposit of the Weald of Sussex shows no such structure; it cannot be traced in the Yorkshire estuary coal field; nor is there any mention of it in any lacus-

trine deposit which has been desiccated and exposed to our observation. It is very doubtful whether it can be recognised in any marine formation, and certainly it does not clearly apply to any class of marine deposits now in progress: at the same time we must admit that, in all cases, the action of the sea growing less and less sensible far from shore where the water deepens, the sediment brought by rivers and floods must be formed in attenuated masses, thickest towards the shores. This effect will be evident in exact proportion to the *falling velocity* of the particles in water, so that pebble beaches may lie in steeper slopes, and cover shorter breadths than sands, while fine clays will spread further into deeper water. (See p. 709.) But all these slopes *in water* are very gradual, so that even against the rocky Eastern coasts of England, the deep waters have been filled up by sediments, which now assume a gently declining surface under the water, and a moderate slope above it.

For all the purposes of our present course of argument we shall therefore assume the law of original horizontality, or very moderate declination of the planes of *widely extended strata*, as amply supported by every needful proof from careful and scrupulous observation. Hence from adequate observations of the position of strata we can tell whether they have been altered in position or not by convulsions operating in those situations precisely.

Another class of appearances indirectly marks the effect of convulsion, either on the spot or at some distant point. When we find traces of a sudden and complete change in the whole course of the aqueous deposits, so that the quiet deposition of argillaceous or calcareous strata is interrupted and preceded by a tumultuous aggregation of pebbles, we know that there has been some access of agitation to the water. This may, according to circumstances, have happened from a periodical or accidental change in the drainage of the neighbouring land, or from some extensive change of the relations of land and sea. The latter cause may be reasonably adopted, provided that we find these indications of agitation very extensive, and provided that in some instances there be proof of the formation of local conglomerates following upon local convulsions. The latter requirement is found to be satisfied in many instances, and of the former it is easy to judge. One more indication of some distant convulsion affecting the relations of land and sea seems to be afforded from the rare case of the occurrence of one bed of marine shells among a vast abundance of fresh-water estuary deposits, (see p. 591.) without any local unconformity of stratification.

Such are the phenomena to be taken as proofs of convulsion: the most important are those which distinctly establish the precise localities of the disturbance. Let us now examine into the mode of argument by which the geological epochs of these disturbances are to be established.

In all investigations concerning the period when an event happened, we may consider the result completely obtained, when the limits of maximum and minimum antiquity are known as precisely as the data allow. In geological inquiries, the answer is always expressed in terms of the scale of relative antiquity of the stratified rocks, and a convulsion is fixed in geological time, when it can be shown to have happened after the deposition of one stratum, and before the deposition of another. If the strata which thus limit the period of the convulsion be consecutive terms of the series of

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deposits, the most precise attainable result is obtained; but if these limiting strata be not consecutive, the age of the dislocation is known only within a given range. An example of accurate determination of the geological era of a convulsion is afforded in the North of England, where the newest of the coal strata are found to be dislocated under the oldest red sandstones of the saliferous system. Instances of less precise determinations are common enough: for example, in the Mendip hills, the dislocated mountain limestone is covered by undisturbed oolite, and, as far as this observation goes, the convulsion may have happened during any part of the long period occupied in producing the coal, red mail, and bas strata. In this case, however, by tracing the line of the dislocation to other localities, other strata are found to be so related to the limestone, as to fix the geological date of its disturbance within narrower limits.

If the dislocated strata be not actually seen covered by others which are undisturbed, another set of data must be employed. It may happen that around the disturbed rocks some newer stratum spreads in such a manner as to give sufficient reason to conclude that it was deposited since the period of the convulsion. This is, in most parts, all that can be observed with respect to the red mail around Charnwood forest, and it would be satisfactory evidence that the slaty rocks of that district were upraised before the period of the new red sandstone, and in fact, we have found instances where the red mail does really cover with level beds the broken edges of slate.

If no horizontal or undisturbed strata be visible in any part of the dislocated tract, either in superposition or in juxtaposition, the limit of least antiquity vanishes, and we are in danger of assigning too modern a date for the convulsion, if the newer members of the dislocated group of strata be concealed, there is danger of ascribing too high an antiquity to the convulsion. It will be prudent to exclude all such cases from the argument: the others seem to be unobjectionable.

There is yet another point of view of much importance to the following investigations. What we have termed the limit of greatest antiquity marks clearly the completion of the convulsion, but the progress of geological inference has brought us to the point of requiring information whether the disturbances were very rapidly effected by one or a few sudden and violent efforts, or operated slowly by small and graduated movements. According to the former view, the whole amount of the dislocation was effected in so short a time that this may be regarded as nothing compared to the long periods occupied in the deposition of the strata, according to the latter, the disturbing agency might be at work during the whole, or some long part of the period of the formation of the dislocated strata, but ceased when their formation was complete. This is not a mere subtlety or needless refinement: it is very important to know which is the true doctrine: we believe it can be ascertained, for all instances where the facts can be clearly known, and thence it would be premature to make any exclusive assertion: the general process of Nature may be satisfactorily inferred.

Proceeding from the clearest indications on this subject towards those which are less easily interpreted, we may remark in the first place that those dislocations commonly known by the name of 'faults' in the strata, (p. 541) which break the continuity of the beds along a certain plane or fissure, and elevate or depress one side,

plainly declare themselves to be the result of single convulsive movements. To be satisfied of this, it is quite enough to contemplate a diagram of the effects, pl. i. fig. 5, 7; but actual inspection of the phenomena will leave no room for doubt that the whole mass of dislocated strata was put into its present relations, not by a repetition of small and gradual movements, but by sudden and violent agency. A repetition of small movements through the whole vast thickness of strata could not fail to break down those clearly defined walls of the fissure which so generally exist, especially among the harder rocks, and leave the fissure filled up with a confused aggregation of all the substances on its sides, instead of a clear space for the subsequent admission of sparry and metallic matter, or regular traces of the movement of these faces on each other.

The extent of dislocation to which the name of fault accurately applies is extremely various, the difference of level thus occasioned being sometimes a few inches, in many 100 feet, in others as much as 200 yards. This makes no difference in the argument, but it serves to mark out in very clear characters the degree of force exerted in each case. It is remarkable that those dislocations which make the greatest difference of level, range through the greatest lengths of country; so that the ninety-fathom dyke, so named from the observed extent of its dislocation, ranges from the Eastern Sea across the whole breadth of Northumberland, and certain dislocations in Yorkshire have ranges of ten, twenty and thirty miles in one straight line.

As far as we know, the greater portion of the convulsive movements, whose production we are now investigating, were accomplished by means of "faults." There are some very extensive dislocations which usually receive, and may perhaps deserve the same epithet, but which, for the purpose of our present argument, wear a somewhat different aspect. One of the most magnificent examples of dislocation in Europe is that grand break nearly along the line of the Western border of Durham and Yorkshire, from near Brampton by Brough and Kirkby Stephen to near Kirkby Lonsdale, the effect of which is to throw down to the West, relatively, the strata of the carboniferous system more than 1000 yards through a length of 70 miles. An axis of slate rocks rises along the line of fracture, which is also partially marked by dykes of greenstone. On the West the beds dip at high angles to the West, on the East they decline gently to the East. No proper plane of fault is traceable in this case of enormous disruption, owing to the circumstances of the country, and we must have recourse to other considerations to arrive at satisfactory inferences concerning the time employed in producing it.

In the first place we may remark, that this line of disturbance is cut off to the North by the ninety fathom dyke, and to the South by the Craven fault; and there is every probability that it is actually continued along the lines of these faults to a direction right angled, or nearly so, to its own course. If this be so, and the whole is one complex dislocation, we may surely conclude that the middle portion, even if not of the same age as the extremes, was produced in the same manner.

Again, the numerous faults of an ordinary character which cross the country in all directions between these great lines of convulsion, seem evidently related to and dependent upon them; a remark which receives corroboration from many other parallel inquiries. Amongst

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these faults it is possible, perhaps, to distinguish two periods of disturbance, the older one marked by a direction nearly East and West, which is that of most of the metalliferous veins, the other by a direction from North to South, which is that of several whin dykes, and some few lead veins. Perhaps these different directions may have taken their rise from the two directions of the axes of convulsion which bound the district.

The connection, however, is sufficiently clear to warrant our applying to those great axes of disturbance the limits of time by which the lesser faults are defined; that is to say, in many instances nearly coincident to the limits of uppermost coal measures and variegated new red sandstone.

Inferences.

It is apparent, therefore, that the evidence which can be collected on the subject of the simple dislocation of the planes of the strata, points to violent internal movement, occupying short periods of time for the accomplishment of the phenomena. There seems to be no mark whatever of gradual or many times repeated efforts.

Some cases of disturbance, however, are of a complicated nature, and may probably be found upon further examination to require the admission of many repetitions of violent movements and pressures on the same region. Such are the extraordinary retroflexures of the calcareous strata adjoining the Alps, the retroverted dips in the coal fields of Somersetshire and Belgium, and the flanks of the Malvern hills. It is not, however, easy upon any suppositions to meet the exigencies of these difficult cases.

What are usually called antichlinal axes of elevation, must, likewise, be considered as yielding insufficient evidence concerning the length of time elapsed from the beginning to the end of the disturbance. In some cases, indeed, the dips on either side from the axis are so steep

that they seem to refer themselves to single and violent movements, but where, as in the Weald of Sussex, the appearances along the axis indicate that there the disturbance has been moderate, while toward the sides it has been extreme, the breadth of the country being considerable, there seems on a first view no very good reason for coming to a decision at all, as to the prolonged or transitory nature of the convulsing agency.

There is, however, an indication worth pointing out for the future guidance of observers on this branch of the inquiry. If we imagine that during the deposition of any class of strata, an antichlinal axis is formed so that they are gradually uplifted and converted to dry land, we may be sure that all the strata would be found to grow continually thinner from either side toward the axis of elevation, at which line they would become evanescent. Very few instances can be quoted where many strata are actually seen to be continuous over the antichlinal line. The Isle of Wight, the elevation valley of Woorlhope, (*Geol. Abstracts*), the Hampshire and Wiltshire chalk, and some remarkable cases in Switzerland, seem to be, however, sufficiently in point, and no traces of such a diminution are there observable.

Upon the whole, then, there is a want of proof that the General disturbing forces were exerted through long periods beneath a given region, so as by many small and repeated convulsions, all operating in the same direction, to give the effect of one great dislocation. On the contrary we may believe, that the time was very limited during which several of the great dislocations and axes of disturbance assumed their respective characters. Yet, owing to the difficulty of the investigation, the question must in many instances be left wholly undecided.

The following Table shows the geological periods of many remarkable convulsions in Great Britain, and the places where some of the most considerable effects are manifested.

No.	Geological Period of the Convulsions	Effects noted.	Localities of some of the Phenomena.
a.	During the deposition of the slate system .....	Production of argillaceous conglomerates .....	Derwent Water, Cumberland
b.	Ditto .....	Porphyry and greenstone and trappean conglomerates .....	Grasmere in Westmorland, Radnorshire, Herefordshire, &c.
I.	After the Cambrian slates and before the carboniferous system ..	Disturbed position of primary rocks ..	The Graupians, Lammermuir, Cumbrian mountains, N. Wales, Crymlyn chain, &c.
1.	During the carboniferous period ..	Production of old red conglomerates ..	The Highland Border, Cumbria, &c.
II.	Before the adjacent rocks of the saliferous system taken generally ..	Marine bed among estuary deposits ..	Yorkshire
a.	During the saliferous period ..	Numerous dislocations, fissures of dykes and veins, antichlinal axes, &c.	In all coal districts of this era, both in Europe and America. Charnwood, Crosswell fault, Craven fault, &c.
III.	After, or during? the saliferous period?	Production of mixed conglomerates ..	North of England, North of Germany.
		Veins of lead, &c. Great or 90-fathom dyke	Yorkshire, Mendip hills, Tynemouth castle, Campsall, &c. border of Cambrian group, (Kirkby Stephen)
	? During the oolitic period ..	Unconformity. Kelloway's rock in contact with the lower oolite group excluding the upper portion ..	Cave, Yorkshire. (p. 631)
IV.	After the oolitic period ..	Unconformity of strata between oolitic and chalk systems ..	Yorkshire wolds, Dorsetshire cliffs.
2.	.....	Estuary deposits. Pebble beds of lower green sand ..	In the Wealds of Kent and Sussex, Lincolnshire, Isle of Wight, &c.
e.	During the chalk period ..	Pebble beds, wasted surface of chalk ..	Hertfordshire, Vale of Thames.
V.	After the London clay ..	Vertical strata ..	Isle of Wight.
3.	.....	Marine deposits between lacustrine beds	Ditto.
f.	.....	The crag ..	Essex and Norfolk.

The Roman numerals are applied in the above list to all periods where considerable movements are traced in direct effects of dislocation and unconformity; italic numerals to those cases where a change in the nature of the water over given regions seems to result from a distant convulsion; and small letters to

mark the occurrence of the most remarkable periods of conglomerates.

The next Table presents the result of a more extended survey of direct convulsive effects on the Continent and Islands of Europe.

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No.	Geological Period of the Convulsions	Effects noted	Localities of some of the Phenomena
I. and 2. E. de B.	Before the old red sandstone ....	Anticlinal axes and great faults of the slate system .....	The Hunsrück and Taunus.
III. 3, 4, 5. E. de B.	Before the new red sandstone ... Before the rothetodteliegende ...	Immense disruptions and faults of the coal system .....	Calvados, South-West border of the Vosges.
	b. Before the zechstein .....	Immense dislocations and faults of coal strata .....	Westphalia, Belgium.
	c. Before the new red sandstone .	Immense dislocations and faults .....	Vosges, and Black forest.
IV. 6. E. de B.	Before the lias.	Mountain ridges of zechstein, &c. ....	Thüringerwald and Böhmerwald.
V. 7. E. de B.	Before the lower green sand.	Abrupt and distorted strata of oolitic system .....	Mont Pilat, Cevennes, (perhaps the Krageburge.)
VI. 8. E. de B.	Before the uppermost chalk beds .	Abrupt elevations of green sand and lower chalk .....	Mont Vais, Devolny.
VII. 9. E. de B.	Before all the tertiary rocks. ....	Elevations of chalk and green sand ..	Pyrenees, Northern Apennines, the Moora.
VIII. 10. E. de B.	Before the nagelfluë .....	Detached ridges .....	Corsica, Sardinia, Auvergne.
IX. 11. E. de B.	Before some diluvial beds. ....	Newest tertiaries uplifted .....	The range of the Western Alps, Diablerets, Mont Blanc.
X. 12. E. de B.	During the formation of other diluvial beds. ....	Some diluvial beds convulsed .....	The range of the Eastern Alps from the Valais to Austria.

Elie de  
Beaumont's  
generaliza-  
tions.

It is to M. Elie de Beaumont that we owe the impulse which the study of the periods of geological disturbance has of late received, and he is the principal authority for the construction of the preceding Table. M. de Beaumont makes twelve distinct systems of convulsions which are supposed to have happened at as

many distinct periods, but we do not find sufficient evidence to substantiate the division into five systems, of the first and second of our Table. The following is De Beaumont's view of these five systems including applications in Great Britain for comparison with the details of our first and second groups.

N	Geological Period of the Convulsions.	Effects noted	Localities of some of the Phenomena
I.	1. Supposed to be during the deposition of the slate, certainly anterior to old red sandstone .....	Elevation of many mountain chains without transition limestone .....	Grampians, Cumbrian group, Snowdon, Cornwall, Hunsrück, and Taunus, Isle of Man, Anglesea.
	2. Posterior to the greywacke slate, anterior to old red sandstone ...	Great faults affecting transition limestone, and anthracitic slates .....	Devonshire, South of Ireland, Bocage in Calvados, South-West border of the Vosges. Harz?
	3. After the coal strata and certainly before rothetodteliegende .....	Immense disruptions and faults of the coal .....	From Derbyshire to Northumberland along the Western border of Yorkshire. Malvern.
II.	4. After the coal strata, certainly before the zechstein .....	Ditto .....	Westphalia, Belgium, Mendip, South Wales.
	5. After the coal strata, certainly before the bunter sandstein .....	Great disruptions. ....	Vosges and Black Forest, from Basle to Mayence.

#### Direction of Convulsive Movements.

Elie de  
Beaumont's  
hypothesis.

It is impossible to make many observations concerning faults and other dislocations of the strata, without being strongly impressed by the fact that they commonly follow certain straight lines through a country, every where producing analogous mechanical movements. The length of their courses is often so considerable that one great dislocation defines the physical geography of a district. It has been long known that in mining Countries the faults take parallel directions, and sometimes two or more systems of dislocations, crossing in certain angles, were found to be of different antiquity. That dislocations were in some respects to be compared to the effects of earthquakes was also well understood, but no one before De Beaumont appears to have carried his notions of the coincidence between the lines of convulsion and the direction of the great physical features of the Globe, so far as to venture on the construction of a general system. This excellent Geologist believes that there is a constant dependence between the direction of the dislocation, and the geological epoch of its occurrence, such that all the dislocations of the same age are parallel to one and the same great circle of the sphere;

and that, in most instances, dislocations of different ages are parallel to different great circles which intersect one another at assignable angles.

It will be readily understood that this general hypothesis is not to be tested by single or small dislocations. It must be examined on a great scale, by means of very exact and numerous data. It is not too much to assert, that in the present state of Geology, the facts known are not clear and numerous enough to support this hypothesis; and on the other hand there are not facts to warrant the unconditional rejection of it. It must be looked upon as a first attempt in a new field, as a generalization carried to extreme; but it is certainly founded on important data, and in several instances agrees well with observation. The principal difficulty of applying satisfactory tests to its consequences, arises from the uncertainty of the exact date of many of the most characteristic convulsions. We cannot positively tell whether the dislocations of the Grampians and Lannermuir, which take parallel courses, were geologically synchronous or not, because the beds dislocated are not the same. Even in the case of the great faults which followed upon the carboniferous system, the limits of the geological epochs of their occurrence are too vague for the application of such a

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theory. In fact, De Beaumont's 3d, 4th, and 5th periods may be actually synchronous; so may his 1st and 2d periods be, because their *limits* are indefinite on the side of the least antiquity. Rothetodteligende and magnesian limestone cover unconformably the coal of the North of England, and thus define the date of the convulsions; but in the South of England these are of rare occurrence, and often entirely wanting, and then the new red sandstone above the coal gives only a vague approximation to geological time.

At present these are irremovable difficulties. We can then, with strict propriety, only examine the question of the dependence of the direction of dislocations on the geological period, by comparing together, first, the directions of those dislocations which are *not* known to be of different ages; and second of those dislocations which are known to be of different ages.

The first system of dislocations is vaguely limited as to time between some part of the primary strata and the base of the carboniferous strata. The direction of the axis of elevation of the Ross mountains, the Grampians, and Lammermuirs, prolonged into Ireland, is North-East and South-West. This corresponds with the general direction of the slaty rocks of Cumberland, the Isle of Man, North Wales, and Cornwall, of the Hunsrück and Taunus. But the direction of the Devonshire slaty rocks is nearly East and West; so is that of the South of Ireland, the Harz, the South-West border of the Vosges, and the Borge in Calvados. M. de Beaumont thinks these two directions belong to two periods, the latter being more recent. This may be true; the hypothesis is not destroyed by the discrepancy, but we must demand clearer evidence of its truth.

The second system is more accurately limited than the former, since the series of rocks dislocated is generally more complete, and the undisturbed strata are of nearly the same antiquity. Three prevalent directions are recognised. The first is nearly North and South from the course of the Tyne to that of the Trent; it is parallel to the axis of the vale of Clwydd and to the chain of the Malverns. The second is nearly East and West, in South Wales and the Mendip hills, and along the Tyne; West North-West and East South-East in Charnwood forest; West North-West and East South-East in Craven; East and West in Belgium; East North-East in the valley of the Meuse and Westphalia; North-East and South West, or North-West and South-East in Shropshire and Radnorshire. The third is North and South, or North-West and South-East, from Basle to Mayence.

Some of these cases of discordant direction occur along the same dislocation, as, for instance, the great Belgian axis of disturbance from Westphalia up the Meuse and through France to Boulogne; in other cases the difference of direction may correspond to a difference of age: but this has not been proved, and ought not to be assumed.

We may now turn to consider the relative directions of dislocations of different ages. M. de Beaumont himself has found several instances of dislocations of unequal antiquity following the same parallels of direction. The North-East and South-West direction of the first system of disturbance is repeated in the fourth. (Seventh of De Beaumont.) The North and South direction of some dislocations of the second system (third of De Beaumont) is repeated in the seventh. (Tenth of De Beaumont.) We shall add some other coincidences. The East and West direction of the South-Wales coal field is

the same as that of the great fractures along the Isle of Wight; the great Cleveland dyke, of 70 miles in length, which cuts the oolites, is nearly parallel to the older elevation of Charnwood and the great faults in Craven. Again, it is a general law of most mining districts to have their principal productive veins running nearly East and West; and crossed by others North and South. Is it to be supposed that veins which are parallel are universally of the same age? Is it not very well known that they are not so?

These difficulties seem wholly insuperable in the present state of the Science. It seems not possible from elements so uncertain and confused to rise, by a legitimate process, to any sound conclusion, at once exact and universal in its application. Any hypothetical connection between geodesical lines and the directions of disrupted strata appears liable to interminable difficulty, from the excessive number and various direction of the dislocations. Any line drawn through any Country, not far removed from a great axis of disturbance, will be found more or less parallel to some of the cracks or faults which depend upon that axis. If, rejecting these minor phenomena, we limit our evidence to the great lines of mountains, the data are too few and too disjointed for satisfactory induction. To show by what evidence M. de Beaumont has himself been led to adopt his hypothesis, we may abstract his original account of two systems of disturbance, the one detailing minute, the other more general evidence.

Three small granite eminences in the Côte d'Or, near Sombernon, which accompany the disruption of Jura limestone there, range in a line North-East and South-West, parallel to the summit ridge of the Côte d'Or. The line of these granite points being considered part of a geodesical circle, and prolonged in each direction, is found to coincide with several remarkable geological accidents or disturbances. In the North-East, for instance, it coincides with dolomitic Jura limestone and steep dips at Suzy, between Langres and Dijon, with the hot springs and magnesian muschelchalk of Bourbonne les Bains, with the basaltic eminence of Essey, South of Lunéville, and with the granitic protuberance of Albersweiler, between Annweiler and Landau.

Another line of disturbance parallel to the preceding is indicated, and it is observed, that from Paray (Saône et Loire) to Plombières, (Vosges,) the great line of valley watered by the Bourbonne and Saône is perfectly parallel. This line prolonged into Germany passes along the line of the valleys of the Main and the Saal, through Mittenberg to Leipzig, and is parallel to the Erzgebirge and Mittelgebirge.

Now all these dislocations were probably produced at the same geological epoch; which, though inferred from the general phenomena along the line, is determined more exactly in consequence of an extension of this system of faults by a series of parallels retiring to the South-East, till we arrive in the Department of the Rhone, where the Jura limestone and chalk occur together, the former dislocated, the latter undisturbed. The direction of these parallels of disruption is at Dijon, North-East and South-West. In the Jura a great number of undulations in the strata range parallel to a line North 40° East, or North 45° East, and, being sometimes filled with green sand deposits, are clearly of the same date as the other disruptions mentioned above.

The insulated chain of the Pyrenees, one of the most

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Ninth system of De Beaumont.

remarkable in Europe, forms the base of the ninth system. Many observations prove that the chalk and green sand are here uplifted with the primary rocks, but the later tertiary deposits lie level against their slopes, and some were deposited from a sea which washed the base of the already elevated mountains. The general direction of the chain, from Cape Ortegal in Galicia, to Cape Creuss in Catalonia, is a little South of East; but this general chain is composed of partial ridges whose axes are parallel to one another, and directed West North-West and East South-East.

This direction belongs to the disturbances of the same date in Provence and near Nice, and is recognised in the Apennines, at least in the Northern part, and in the Country of Naples, and along the South shore of Sicily. The South-Western boundary of the Nægelflue, in Switzerland, appears to correspond with the Pyreneo-Apennine line, as do likewise the Dalmatian and Croatian summits, the valleys of the Save and the Drave, the line of the Rhodopean mountains, and the ridge which crosses the Straits of the Bosphorus. Similar directions seem to be traceable in Greece; and as far as the evidence yet collected goes, the date of the elevation of all these chains is the same. The Carpathian range, parallel to the Dniester, falls into the same system with a small line of granitic and syenitic rocks along the Elbe near Dresden, and the mean courses of the metallic veins of the Harz.

Extending his views, M. de Beaumont finds some traces of the Pyreneo-Apennine system in Africa and Syria, in the Caucasus and the Ghauts of India; but the imperfect state of information concerning the Geology of these Countries renders the inferences concerning them of less value than those which relate to the North American mountains. On prolonging the Pyreneo-Apennine circles across the Atlantic by Hecla and Greenland to the New World, we find it descend parallel to the Alleghanies and their Northern connections, which have determined the form of the Eastern shore of North America; and, as appears by the statements of Transatlantic Geologists, were probably uplifted between the age of the chalk and the latest of the stratified rocks.

Such remarkable accordances of epoch and linear direction, over so enormous a length upon the surface of the Globe, cannot, says De Beaumont, be the result of chance, but of a regularly acting internal cause. Those who admit the generalization, usually imagine the effects to depend upon periodical fractures of the crust of the Globe through the cooling of its interior, so that the crust contracts convulsively with lines of fracture parallel to some great circle of the sphere.

Relinquishing for the present any further attempt to construct a general system of relation between the age and direction of dislocations, we may still find it useful to inquire what laws of direction belong to dislocations in a limited district.

The remarks already made, pp. 543, 544, 597, 598, and in the Section on Mineral Veins, will render it unnecessary here to do more than state a single case of the parallelism of trap dykes, which has been furnished by Archdeacon Verachoyle, in the North-West part of Mayo and Sligo. (*Proceedings of the Geol. Soc.* 1833.) He describes no less than eleven basaltic and amygdaloidal dykes, which, in a space of  $11\frac{1}{2}$  miles in breadth, traverses the Northern part of the district in a nearly East and West direction, and cut through all the formations from the gneiss to the carboniferous limestone

One of these dykes he traced between 60 and 70 miles, and believed it might be followed much further to the Eastward. Two of the dykes are crossed by others having a North and South direction.

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#### Direction of the Strata.

It was long since remarked by Mitchell, that the direction of the strata in any region was generally parallel to the ranges of mountains; a truth of great importance in the modern system of Geology. The prevalent range of the strata in any Country must, however, depend partly upon another circumstance, viz. the original line of the Ocean boundary. In many parts of the Globe the most prevalent direction of the strata is observed to be North-East and South-West. Humboldt was so struck with these *loxodromic* lines in Europe, that he says one of his principal inducements to visit Equinoctial America was to examine the directions of the strata there. He has furnished evidence that the parallelism of the strata to the great lines of mountains, is a general law of Nature.

M. Necker, in a communication to the *Société d'Histoire Naturelle de Genève*, has shown a very unexpected coincidence over large portions of the Northern hemisphere, of the direction of the strata, and the curves of equal magnetic intensity, as traced by Captain Sabine. One of these curves, that of 297 seconds, traverses Scotland in a direction North-East and South-West, which is exactly that of the strata; it keeps the same direction by Christiania in Norway, where, according to M. Von Buch's observations, the strata trend North-East and South-West, and pass through Sweden, where, according to Hisinger, the same direction of strata predominates. On arriving at the Gulf of Bothnia the magnetic curve turns North-West and South-East, which, according to Strangways, is the direction of the Southern border of the Swedish and Russian granite.

M. Necker's inferences.

The curve of 308 seconds enters Europe by Lisbon, and passes South-West and North-East through the Spanish Peninsula, which is nearly the line of most of the long Sierras between the great rivers; it passes by the Cevennes, and goes parallel to the Alps in their North-East course to the Tyrol, but there turns South-East, as do also the lines of stratification through Carniola, Istria, Croatia, Dalmatia, and the Morea. Parallel to these are the Carpathian mountains. The same correspondence between the magnetic curve and the lines of strata is traced through the Crimea and along the Caucasus.

In North America the magnetic curve and the stratification range North-East and South-West along the whole Eastern coast; in the Rocky Mountains both extend from North North-West to South South-East: in Mexico the magnetic curve takes the parallel of the Cordillera of Anahuac North-West and South-East, and ranges along the South coast of New Spain. Further to the South the curves resume their course North-East and South-West, which, according to Humboldt, is the direction of the strata in Venezuela, and between the Orinoco and the Amazona. The mighty chain of the Himalaya, which in Nepal bears North-West and South-East, and turns North-East at the North-East extremity of Bengal, is parallel to the curve of 297 seconds which was first noticed.

These remarkable accordances deserve the attention of Geologists, who must always receive with particular gratification any results tending to connect the general facts of the construction of the crust of the Earth with the laws

More liquid inquiry.

Geology. of the distribution of terrestrial magnetism, electricity, and temperature.  
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*Effects of Convulsions in altering the Relations of Land and Water.*

The submarine origin of the whole stratified crust of the Earth being admitted, and the actual elevation of these rocks above the sea in the existing continents being known, it is required to determine the several geological periods when different parts of the solid land were raised above the waves. It is usually taken for granted that this effect has been produced by the several systems of convulsions which have impressed angular movements upon dislocated portions near the surface of the Earth, and thus raised some portions and, perhaps, depressed others. That this general impression is frequently well founded, though it does not embrace the whole truth, will appear from the simple consideration, that the whole configuration of the dry land, whether in islands or continents, is dependent upon the direction and elevation of the chains and groups of mountains, which were certainly elevated, at various assignable geological epochs, above the ancient sea.

It may be asked how is this ascertained? The mere fact of those mountains being convulsed, and the strata therein thrown into angular positions, does not seem to prove that the region was elevated by such action above the level of the sea, nor, perhaps, that it was uplifted at all; since it may be imagined, with some theorists, that the neighbouring parts were depressed, and that the general level of the Ocean has been lowered. In answer to this we may proceed to show that the effect of the convulsions was relatively to raise the convulsed parts; that these parts were in several instances elevated above the sea at assignable periods; and that these effects were independent of any imaginary depression of the general level of the Ocean.

Elevation  
the consequence of  
convulsion.

That the effect of convulsions has been, generally, to raise the convulsed parts will appear shown by considering what is the focus of the disturbance and the direction of its energy. The mountain chains and groups are most certainly the foci of the disturbing forces; for as we pass towards them, from all sides the number and force of the dislocations continually increase, and the declination of the strata grows more and more violent. The direction of the disturbing force is by the same process of observation clearly discovered to be vertical or nearly so, and outwards from the central regions of the Earth. It was an expansive force, which employed its principal efforts along certain lines and about certain centres, there breaking and bending the strata in the highest degree, but also lifting them up on all sides around. As far as we can judge, this elevation of the mountain chains and groups was generally unaccompanied by any neighbouring depression, for the inclination of the strata for the most part gradually subsides to a gentle slope, and finally vanishes in nearly horizontal planes. In the mountain chain itself, various and suddenly reverted dips may be met with corresponding to the violence of the disruption, but by a careful study of the exterior slopes the general tendency of the convulsion may be clearly deciphered.

The same data will not, however, by any means give us right to conclude that the mountains so uplifted were raised above the sea, because, though we may know the absolute height of the vertical movement, this will avail

us nothing in our ignorance of the original depth of the water. We must examine to see whether they bear on any part of their surface any traces of those later marine deposits which spread around their bases. If they do, we may be sure they were not elevated above the sea till after the date of these strata; as for instance, the Alps, which bear upon their crests portions ofoolitic, crustaceous, and tertiary strata, are thus proved to be of modern elevation. If they do not, and the newer marine strata around their bases have been deposited horizontally against the slopes of the mountains, we are entitled to believe that these had been previously reared above the sea. This conclusion, however, it must be always borne in mind, does not inform us correctly to what height they were reared above the sea, but leaves us to infer that they have since partaken of another movement by which these newer strata have been placed at their present elevation.

The facility of escape from many embarrassing considerations which a general depression of the level of the Ocean seemed to offer, was too tempting to speculators in Geology to permit them to inquire into its physical probability. The simple question of what has become of the vanished water was disregarded by Werner, and perhaps never thought of by his followers. It will not now be sufficient to press it into a subterranean abyss, nor to carry it off to other planetary regions in the tail of a comet; we must admit that the quantity of water upon the Globe has been constant, or give up all pretence to philosophical moderation; and with this restriction upon our inquiries it becomes easy to prove that the level of the Ocean is confined within very narrow limits of fluctuation, so long as the Earth's axis and rotatory velocity are supposed invariable. If the level of the Ocean be expressed either by taking its mean depth, or the mean radius of its surface, this level may be supposed variable by reason of any local convulsive movements of the dry land or bed of the sea, any change of dimensions of the whole Globe, or any alteration of the mean temperature of the water. First of temperature. If we take the mean temperature of the Ocean at the Equator 51.5 F. its temperature at the Poles 0.0 F. on the surface, and at some depth ( $d$ ) 81.5 F.; and suppose, in conformity with inferences from organic remains, that the whole surface of the Globe was formerly subject to a temperature equal to that of the Equator; the Ocean at that period must have been defined by a longer radius.

Speculations on the  
Ocean level.

The expansion of the Polar waters, supposing them to have been fresh, would be at the surface only to the extent of 4°.0, because at temperature 0°.0 F. fresh water occupies nearly the same space as at 77°.5; at nearly half the depth ( $d$ ) it would expand through 42°.75, at the depth ( $d$ ) nothing. Average expansion = 22°.4

Variable  
with change  
of temperature.

which corresponds to  $\frac{1}{184}$  of the depth. If we suppose  $d$  to be 10,000 feet, the Polar expansion = 54 feet. But if we suppose the water to have been salt, the expansion at the Polar surface, from 0°.0 F. to

$$81.5 \text{ F.} = \frac{81}{180} \times \frac{1}{20} = \frac{81}{3600} = \frac{1}{44} \text{th}$$

of the depth: and at other latitudes

$$= \frac{1}{44} \times \sin \text{lat. And } \frac{10000}{44} \text{ feet} = 228 \text{ feet,}$$

which would give a mean rise of the Ocean = 76 feet.



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It is evident that such fluctuations of level, however real, are not adequate to explain the desiccation of large tracts of land.

What might be the effect of a general change of dimensions of the Globe, through variation of its own temperature, is beyond our power of investigation, because we do not know in what ratio the solid and liquid parts of the Globe would alter their dimensions.\*

We may, however, consider the effect of a general change of dimension of the nucleus of the Globe, supposing the superficial temperature unaltered. According to all analogy of organic forms, the Globe may be supposed to have grown cooler continually, and thus to have contracted in bulk; but this, by shortening the mean radius, would cause the Ocean level to rise upon the land, which is contrary to the effect we wish to explain. If we even allow, for the sake of argument, an augmenting diameter to the Globe, this must go to a very great amount before the level of the Ocean, as compared to the land, would be sensibly affected. If the Ocean be 5 miles deep, the diameter of the Earth must be augmented  $1\frac{1}{2}$  miles to cause the level of the water to sink relatively 10 feet, and to sink it half a mile the radius of the Ocean must augment 400 miles. It is unnecessary to prosecute this inquiry, for a sinking of half a mile would be insufficient for the desiccation of the whole dry land, even allowing the great mountains to have been uplifted.

Variable  
through  
internal  
movements

The most interesting part of the inquiry remains to be more carefully examined—the variability of the Ocean level in consequence of displacements of the solid land. We shall put the case in three forms, and according to each of these imagine the present continents to be depressed beneath the waters of the Ocean, as they once certainly were.

First, we may suppose no vacuum to exist below the crust of the Earth, nor any receptacle occupied by air or gases into which the solid land could sink, but that a sinking in one place should be compensated by a rising in another, so that the cubic dimensions of the Globe should remain unchanged. Moreover, to put the case to extreme, it may be a condition that the land shall sink so that water shall cover the whole surface. In this case the level of the Ocean would rise, that is, the mean radius of its curved surface would be lengthened, by a quantity depending on the mass of the solid land submerged, and on the relative area of land and water. This relation of area is about as 3 water to 1 land. The cubic content of the solid land may be thus estimated. In England, Wales, and Scotland, the average height of those conspicuous mountain masses which appear to give shape to the whole country is about 8000 feet; and if we consider this as the apex of a cone whose base is the given area, we shall have the cubic content of the mountain masses =  $\frac{3000}{3} \times \text{area}$ . But on account of the valleys this quantity must be reduced to half, or

$= \frac{3000}{6} = 500$  feet, and the area =  $\frac{1}{2}$  of the whole area of the Island. In addition, the more level parts may be compared to a mean cone of 400 feet altitude, on an area =  $\frac{1}{2}$  the whole area of the island. Then  $\frac{400}{3} = 133$

feet, and making the sum of the bases = area of the Island, we have mean altitude  $\frac{500 + 400}{4} = 225$  feet.

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This principle applied to the Continents of Asia and America would give in round numbers about 1000 feet mean altitude of land; and as the area of the expanded Ocean would be four times as great as the land is now, the total mean elevation of the water, by the submersion of the whole mass of land, would be about 250 feet; a quantity too small to be of use in explaining any but the lesser order of geological phenomena, and which may be considered as the extreme limit of oceanic rise.

Secondly. We may suppose the existence of cavities into which the solid land might sink, so that there may be no elevation in another place corresponding to the given depression. To put this also to extreme, we may imagine the very improbable case that a mass of solid materials equal in bulk to all the solid land above the water, should sink into a cavity, and that the surface of the submerged land should be level. The level of the Ocean would be nearly unaltered, except in a small degree, by reason of its shallow expansion over the area of the land. We might go on to suppose even the enormously improbable case of cavities existing so large as to admit twice the whole solid mass of the continents, and that these should sink with an equal bulk of materials into these cavities. Even in this case the Ocean level would only be lowered 250 feet.

Thirdly. If we suppose contemporaneous or successive elevations and depressions however extensive, the Ocean level would oscillate about a constant line.

It is evident, therefore, that by no stretch of conjecture, that is not absolutely monstrous, can we torture the known laws of terrestrial arrangements into agreement with the hypothesis of any but small changes of the level of the Ocean; a conclusion of the highest value, since it enables us to argue upon that level as a general standard to which we may refer all the effects of internal movements, in whatever period, and by whatever forces produced. It must be remarked, however, that it fixes no limits to the effects of the temporary violence induced in the Ocean by such movements, because these effects would be proportioned to the impulse with which they were attended.

Conclusion  
adopted.

It appears that we cannot in all cases understand the possibility of the elevation of land out of the sea by the mere effect of local convulsive movements, but must in addition admit the gradual rise of large tracts of land whether convulsed or not at some earlier epoch. England is an unexceptionable example; and probably every Country will be found to require the same admission. The necessity for admitting this gradual elevation of the whole country, is first suggested by the difficulty of otherwise accounting for the altitude of the tertiary and other marine strata, which have been deposited long since the great convulsions which partially or completely raised the primary and other old systems of rocks, and are, in general, remarkably free from the traces of any such events. The older Geologists relieved themselves from this dilemma, by inventing the gradual diminution of the level of the Ocean; the moderns meet the difficulty by supposing a gradual intumescence of the land. The former mode has been proved to be incredible, the latter we certainly do not yet understand, but it is not at variance with the established facts of convulsive elevation.

Where convulsive movements can be traced in their

\* Since this Section was written, Mr. Babbage has made known some very interesting views bearing on this subject. (Proceedings of the Geol. Society, 1834.)

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effects we have a good local cause for the local elevation of the ancient bed of the sea; but where no such movements can be traced, and yet the land is raised far above the sea, it is clear that we must neither admit convulsions, nor deny the relative change of level of land and water. Now the areas of country which are elevated, but not convulsed, in such a way as to account for this elevation, are very extensive. The greatest portion of the level regions of the Globe is thus circumstanced. In many instances we might plausibly explain the facts by supposing that the same localities (as mountain chains and groups) which had been in very ancient periods liable to great convulsive movement, were during later periods influenced by more gradual and continual subterranean expansion, so as to bear up on their slopes the newer strata formed and in process of formation. This would apply to England, whose great centres of old convulsions are nearly confined to the Western borders, and it seems equally suitable to most Countries whose lines of mountains correspond with the general figure. The principle, once admitted however, will be found applicable to all situations, and equal to solve a very difficult class of problems in Geology. It may even clear our way through cases of alternate elevation and depression, such as the Temple of Serapis on the Neapolitan shore: for whatever be the cause of local intumescence, it may be discontinuous or intermittent, and elevation in one quarter may be counterbalanced by depression in another.

Proposal of  
a hypothesis on  
this subject

But is such an assumption of local subterranean expansion consistent with what is known of the interior constitution of the Globe, or is it a vain speculation? So little is known of the interior of the Globe, that almost any hypothesis is safe from coming into collision with that knowledge, provided it allows of given mean density, and a specific gravity increasing toward the centre. Newton supposed the spheroid to be homogeneous; it has been found that this supposition is by no means necessary to fulfil the observed conditions of the problem of the Earth's figure, and the irregularities of attraction indicated by the pendulum experiments, and of curvature by direct meridional measures, seem to show that the concentric masses of the spheroid may not be of uniform density.

This being allowed, there would seem no objection to suppose that the densities along any one radius of the spheroid are variable, by reason of intestine movements among the unequally dense parts of the concentric masses, and this would exactly answer the conditions of the geological problem. For the length of any radius of the heterogeneous spheroid would necessarily vary with the densities; and considering the small proportion of the height of the land above the mean radius of the latitude, it is clear that small internal changes in a length of 4000 miles would easily account for variations on that line to the extent of 1000 feet or yards.

This hypothesis would give a gradual and prolonged elevation in some parts and corresponding depressions in others; it would not affect in a sensible degree the astronomical elements of the Planet, but would change more or less completely its hydrographical boundaries. It appears consistent with the inference to which we were conducted while studying the phenomena of mineral veins, (p. 777.) viz. that under the same region of stratified rocks different sorts of igneous rocks had been at different times developed; and at all events may be used as a first contribution toward a sound mathematical

theory of general subterranean movements independent of volcanic convulsions.

We may now attempt a brief sketch of the relations of land and water in particular regions, during the successive geological periods, and notice the character of the agencies concerned in producing them.

It is sufficiently evident that we are precluded from any attempt to assign these relations generally, because we cannot know what tracts of land were once raised above the sea, and have since been submersed. This applies with great force to the periods, whatever they were, which preceded the formation of what we call primary strata; for concerning the question of the existence of land during those periods we cannot even offer a conjecture, except upon the basis of inquiries into the remains of terrestrial organic forms imbedded in these strata. The evidence which they afford negatives, as far as it goes, the existence of land plants; but it is chiefly by the great extent and uniformity of character of these deposits, and by the absence from them in the lower parts of marks of littoral or fluvial action, that Geologists might justify a belief that little or no dry land divided the wide primeval Ocean. We pass to consider the state of things during the primary period.

It is admitted that the greatest effects of the elevatory movements which can be traced in the existing ranges of mountains were posterior to the primary deposits; but there are good grounds for believing that dry land in some (unknown) situations began to furnish vegetable reliquia, during, perhaps, the whole of the period occupied in the deposition of the clay slate system. *First*, there is the certainty that some disturbing effects of igneous agency are traceable among very old members of this vast group of rocks. (p. 571.) *Secondly*, the existence of carbonaceous matter (anthracite) among the newer slates. *Thirdly*, according to different authors, in the upper parts of the series occur various land plants.

It is highly interesting to observe the coincidence of two classes of results bearing on the relation of land and water at this epoch. Some of the most extensive and important physical features on the Western side of the basin of Europe have resulted from convulsions preceding this epoch, which certainly raised out of the sea many remarkable ranges of high ground; and the most considerable accumulations of land plants which have furnished the substance of coal in Europe and North America, followed those convulsions. It may, perhaps, eventually be possible to derive, from the comparison of the local centres of elevation with the limited fields of coal, some conclusions as to the place and other circumstances of growth of the vegetables; at present we shall only venture three remarks. 1. The deposit of coal plants does not in general follow immediately, but after some interval, the uplifting of certain tracts of land; for between the uplifted primaries and the phytiferous secondaries, great thicknesses of conglomerates holding few or no plants, and beds of limestone full of marine shells intervene. 2. The plants which most predominate in the older parts of the carboniferous deposits in Great Britain (conifers) appear like the vegetation of a mountain district in a warm climate, while those which abound in the younger deposits of the same period (acetiaceæ, equisetaceæ, &c.) may be more successfully compared to plants of plains and marshes. 3. The coal basins appear related in position to the ranges of primaries uplifted before the deposition of coal, and not to those of subsequent ages. This is an important fact,

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primary  
period.At the com-  
mencement  
of the car-  
boniferous  
epoch

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and must be further developed. On the Geological Map of the British Isles, (pl. i.) the local relation of the primary and carboniferous strata may be seen, and it will be observed that the latter form a broad belt parallel to the general course, entering into the indentations, and surrounding the insulated eminences of the former. But along the ranges of the Alps and Pyrenees, no such bands of carboniferous rocks occur. The British primaries were uplifted *before* the carboniferous period, the great European ranges *after*. Coal is, however, not uniformly spread over all the area of the carboniferous rocks. It occurs in the great valleys of the Forth and Clyde, *between* the Grampian and Lammermuir ranges, in valleys of the Lammermuir; (Saqihar;) *round* the Cumbrian mountains; *round* the Welsh mountains; in hollows of the Anglesea primaries. Besides these remarkable juxtapositions, the long range of the great Northern coal fields is still partially united with the coal deposits encircling the Cumbrian and Welsh mountains; and it is only by the effect of immense subsequent convulsions, and the consequent unconformity of the saliferous formation, that it does not now appear completely united with them.

The immense coal deposits of Ireland are in the same way surrounded by primary strata, which were raised above the sea before the accumulation of the coal. Parallel to the Hunsrück and to the Taunus and Ardennes, which were elevated about the same early period, lie the coal deposits of Saarbrück, the Netherlands, and Westphalia. Comparing this statement with the inferences concerning the growth of the plants of the carboniferous period, (p. 594—597.) and with the peculiarities of the several coal fields, we seem to find a fair basis for reasoning concerning the original habits of fossil plants, which may eventually lead to important results.

Before the  
saliferous  
epoch.

The elevatory movements consequent upon the deposition of coal appear to have been very general and extensive, and in the basin of Europe to have materially contracted and altered the boundaries of the sea. In England, especially, this effect is clearly shown, by the rising above the sea of the large tract reaching from the Tweed to the Trent, and including nearly the whole of the space between Berwick, Carlisle, Liverpool, and Nottingham; thus forming a large and nearly united tract from the Pentland Frith to Cheshire. To the same periods we must refer a large augmentation of the previously elevated regions of Wales. It will thus appear that nearly all the Northern and Western parts of the Island of Great Britain were then raised above the sea, which still flowed over the sites of all the Midland, Eastern, and Southern Counties. The greater part of Ireland had also emerged. Besides these greater elevations, some smaller tracts, which now appear as detached groups of mountains, were then conspicuous as islands. Charnwood forest, the Dudley district, and Mendip are examples. The Cumbrian mountains were half surrounded by a sinuous arm of the sea, which washed the feet of the Penine chain from Kirkby Stephen to Brampton, expanded into the Southern Counties of Scotland, and perhaps connected itself along what is now a part of the Irish Sea, with a great diversified gulf in Cheshire, Warwickshire, Leicestershire. (See Map, pl. i.) To the East of a line drawn from Newcastle through Nottingham to Exeter, we may suppose it to have been all an open sea as far as the Ardennes and the Harz. It thus appears that some of the marking features of British and European Physical Geography are of very high antiquity; and however modified in detail, by sub-

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sequent internal movements and superficial wasting, their larger proportions and general effect in those early periods may be very well judged of from the characters which they retain at present.

It might appear that, during the saliferous period, the elevated lands nourished no great profusion of vegetables; for throughout the whole of Great Britain the magnesian limestone and new red sandstone system is wholly, or very nearly so, devoid of such remains; and though in a few places in Germany plants are found in some parts of this system, they rather confirm than oppose the general inference.

It does not seem possible to trace any close dependence of the local character of the saliferous system upon the circumstances of the Physical Geography of the region; for, correctly speaking, there is very little of *local* character, except what is imparted by the unequal extension of the limestone groups; and these are probably wholly derived from marine decompositions. Along the Vosges mountains, perhaps, a peculiar sandstone conglomerate may have been derived from these mountains.

Scarcely any thing in Geology is more remarkable than the great uniformity of appearance of such extensive deposits as those of the saliferous system, with such few remains either of marine or of terrestrial reliques. The prevalent red colour of this system is of itself a circumstance of great interest, though of unknown origin. In many cases this colour is derived from a superficial coating of oxide of iron round the internally clear quartz grains; and there can be no doubt that chemical agencies were then in operation of a very extensive and very remarkable kind. It is difficult to avoid believing that the life of the marine mollusca and radiaria was much controlled by these agencies.

Before the  
oolitic  
epoch.

The deposits between the coal system and the tertiary succeed one another so regularly in England, and even throughout Europe, that it is perhaps impossible to explain the successive parallel outcrops of the several strata, except by supposing a gradual elevation of the pre-existing land, or a gradual retreat of the Ocean. This problem becomes, however, still more intricate when we add the following general truths: 1. That in England the oolitic strata, which succeed the red marls, form hills of greater height than *any one point* of the saliferous formation; the same is true for Germany and France. 2. That there exist beyond the general range of the oolitic outcrops, many far detached hills of these strata resting on and overlooking broad plains of red marl, which seem to be in an undisturbed position. It is obvious in these instances that the surface has been subjected to enormous waste by the violence of watery currents; in every theory of diluvial or alluvial action it is supposed that these denudations were performed upon the dried and elevated land; but few speculators have had the boldness to attempt the solution of the difficulty, by assuming that the *inversion of relative level* between the red sandstone and the oolitic systems is wholly due to the wasting action of water.

Perhaps we shall best consult the true interests of the Science by not insisting much upon any mode of accounting for these yet insufficiently examined questions; but it seems right to observe, that a gradual elevation of the South-Eastern parts of England, parallel to the line of the oolites, and prolonged in duration through the whole period of the saliferous, oolitic, cretaceous, and tertiary rocks, would fully agree with the general physical features of the surface of the district, the minute inequalities of

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which may certainly be ascribed to superficial watery action. This view appears to agree well with the general character of the upper saliferous, oolitic, and cretaceous deposits, which exhibit many repetitions of analogous rocks and fossils, many deposits of limestone and clay, such as might be formed in quiet or deep waters, with but few beds of sandstone. From some of these local sandstones we learn the fact, that some parts of the land which borders the ooliferous sea, nourished a variety of plants, characterised upon the whole by a predominance of vascular cryptogamia and coniferous phanerogamia, different from those of the older coal tracts.

#### *Effects of Convulsions on the Deposition of Strata and on Organic Life.*

The formation of extensive conglomerates has been already shown to be a natural consequence of convulsive movements; and it is in some cases very probable that the disturbance was centred in the immediate vicinity of these accumulations. But it would be a gratuitous contraction of a very interesting field of research to limit our inquiries into the effects produced by subterranean movements on the deposition of strata, if we did not take into consideration the peculiarities of mineral character belonging to the several systems of marine deposits, the alternations of marine and fresh-water rocks, and the successions of races of organic beings. What dependence there may be between these phenomena on the one hand, and subterranean movements on the other, will undoubtedly be revealed by the progress of inductive Geology, and results of a very interesting kind will flow from such a discovery. At present, we can only sketch a dim outline of a subject as yet scarcely emerging from obscurity.

#### *Mineral Characters of the Systems of Strata.*

Actual pro-  
cess of  
nature.

Sedimentary deposits, whether they are occasioned by the action of streams and floods from the land, or of tides and currents in the Ocean, have a mineral character depending on the nature of the materials acted upon. The same great stream may, according as its different feeders predominate in their action, deposit materials of different quality; there may be in such deposits effects depending on the season of the year, but all such differences are periodical, and a series of alternations of given mineral aggregates is the result.

The action of the tides in a certain direction, is also liable to periodical variations of intensity; the coasts worn by tides may be unequally affected at different times, and the accessions of materials from the land may be irregular; still these minute inequalities are almost wholly lost when we contemplate the average results of a long-continued course of the same tidal action.

Deep-sea currents, so long as they follow the same channels, can hardly be supposed to produce any but very uniform admixtures of sedimentary ingredients.

When, therefore, we find a series of sedimentary strata to consist of repetitions of the same materials, or of recurring alternations of different materials, the whole is reasonably referred to a series of the same, or similarly alternating effects of watery action upon the same tract of land, the same line of coasts, or the same channels of the sea.

On the contrary, the suppression of one class of deposits, and the production of another, clearly marks out to us that the water has ceased its action on the

land, coast, or Ocean bed, which it formerly wasted, and transferred its attacks to a new quarter.

It was not the perception of these simple laws of modern nature but a clear recognition of their effects in older periods, that led Geologists to agree in classing together portions of the innumerable layers or strata into certain groups or formations, according as they are identical or analogous in their nature, very gradually change from one to another, or consist of a series of recurring mineral terms; and in dividing these groups at the points where new terms appear and old ones are suppressed. Thus the suppression of red marl, and the introduction of blue clays, marks the boundary of the saliferous and oolitic formations; the suppression of oolite, and the introduction of green sands, marks the limit of the oolitic and cretaceous formations.

Whatever view we adopt of the origin of sedimentary rocks, there can be no doubt that, even from the earliest geological period, the bed of the sea must have been composed in different regions of different materials; this must have been the case, even if we carry back our thoughts to that remote epoch where we may suppose that nothing solid existed at the surface of the Globe, except the products of heat; for these, in fact, contain nearly all the varieties of minerals, and nearly all the elements of the composition of stratified rocks. The very earliest formations which we have yet succeeded in tracing, exhibit themselves in two very distinguishable masses; the gneiss and mica schist system on the one hand, and the clay slate system on the other. When, by the partial elevation of these rocks above the level of the sea, the Ocean was divided into separate parts, local differences of the sedimentary, and even chemical deposits, must speedily have resulted; and as the extent of land increased in any particular region of the Globe, the deposits in the residuary seas thereabout must necessarily have become more and more dissociated from those of other regions.

It is, therefore, very evident that there can be no universal strata; that during the greater part of the geological periods, rocks of very different nature may, and indeed, must have been contemporaneously deposited; although, according to the circumstance of the cases, the peculiar products of one region may have been, by oceanic currents or other causes, mixed with those of another, and so a continual or interrupted analogy between the series of strata in each maintained.

We have now arrived at the point when the coordination of the diversity of sedimentary aggregates in a given oceanic basin with subterranean movements, and the dependence of the former on the latter, may be presented in the form of a very probable inference. Geologists have long been accustomed, while reasoning on the phenomena of tertiary rocks, to recognise the principle of the dependence of the local difference between contemporaneous strata in different basins upon the physical structure of the region from which the materials of these strata were derived. It has been already shown that the successive diversity of strata in the same basin can only be understood by admitting that the different sediments were brought from different regions; it is evident that for this end the drainage of the land, the flow of the tide, or the direction of oceanic currents, must have been changed; this can only be ascribed to an alteration in the local relations of land and water, that is to say, to subterranean movements.

When this change of the sedimentary deposits is sud-

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den and complete, we may generally feel assured that it is owing to violent subterranean movements, which have opened a new communication with the basin; the exact site of the centre of convulsion may perhaps not be ascertainable, though in some particular instances the direction of the new currents may be inferred, and thence their local origin conjectured. When the changes of sediment are gradual or alternate, we must apply corresponding inferences with greater caution.

In some cases slight movements might accomplish great changes in the nature of the deposits. The map of the terraqueous Globe shows us how easily, at particular places, the waters of different oceanic *alvei* might be brought into union by the lowering of an isthmus or the opening of a strait. If the Mediterranean were connected through the Red Sea with the Indian Ocean, would not the deposits in each of them be reciprocally influenced? Such internal movements as might occasion this appear trifling when compared to the disturbances which we know to have been many times effected within the range of geological chronology.

#### *Successive Races of Marine Animals.*

Local  
change of  
organic  
life

If, in consequence of internal movements, a given basin was opened to the reception of currents and sediment from a new quarter of the Ocean, it could scarcely happen otherwise than that a change should arise in the inhabitants of that basin, by the extinction of some, and the introduction of other species. If we except the earliest series of fossiliferous deposits, there is nothing in Geology to indicate that the distribution of species over the Globe was regulated by different laws from those which now prevail; the superficial temperature of the Globe was perhaps more equable, and for this reason organic forms might be more extensively distributed, there might be less local distinction than at present, but yet each species had its definite boundaries, and different regions were characterised by peculiar races.

Upon the establishment of a communication from one such region to another, there must necessarily be a *transference of organic life*, at least in one direction, according to the locomotive habits of the creatures, and the influence of currents upon them and their ova, and other circumstances.

It was with this in view that the passage (p. 553.) relating to the succession of races, corresponding to successive deposits, on a given part of the Ocean beds, was written.

How remarkable is the coincidence of great convulsions, decided changes of mineral aggregations, and substitution of new organic remains, needs only to be mentioned; for these three orders of effects are all combined in modern Geology to characterise the groups or systems of stratified rocks.

#### *Fresh-water and Marine Alternations.*

Few geological phenomena declare more plainly their dependence upon ancient convulsions than the alternations in a given basin of strata, of fresh-water and marine deposits. Not that in every case where we see fluviatile or even lacustrine shells alternating with marine exuviae, we must suppose the levels of land and sea to have been changed, because at the mouths of some rivers this might happen from the bursting of a lake, a violent inundation, or even the natural course of things; but when, as in the coal field of Yorkshire, over

the marine deposits lies a great mass of matter derived from the land, and in this a particular layer of marine exuviae; when, as in the Weald of Sussex, we observe above the marine deposits of the oolites a great thickness of fluviatile deposits covered by marine green sands; or, as in the Isle of Wight and the basin of Paris, see really lacustrine marls and limestones interposed among really marine strata; the conclusion seems inevitable that these are effects of changes in the relative level of land and sea. It would, however, be too much to assert in every case that the internal movements were centred near the places where we witness some of the effects; on the contrary, we may perhaps probably often be merely looking upon the consequences of convulsions which happened at great distances of space, and which produced near their centres of action wholly different phenomena. This mode of interpretation applies very well to those instances in which repeated alternations of marine and fresh-water productions occur without any indications of corresponding local disturbance. (See p. 591.) As an example, we may cite the marine lacustrine formation of the Isle of Wight. (p. 674.)

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#### *The Weald of Sussex.*

One very obvious effect of convulsive movements, whether sudden or gradual, must always be a more rapid rate of waste, both in the land and along the coasts, than usual. It will, no doubt, be possible hereafter to draw from the *varying rate of sedimentary aggregation* in a given basin, some important evidence concerning the amount and duration of the internal movements which caused a more than ordinary accumulation of materials in the sea.

Applied to a case proposed by Mr. Lyell

By combining with this the results of an inquiry into the local site of the convulsion, as inferred from the direction of *new sediments*, we may eventually be able to point out, with more or less probability, the original sites of these materials, and thus show how in ancient periods the wasting of one given tract of elevated rocks, has contributed materials for the accumulation of new deposits in the sea.

So long as, in the prosecution of this research, we confine ourselves to the methods of the inductive philosophy, our progress will be real though slow; new circumstances will arise to quicken the process and solidify the results, and light will gradually break in upon the yet obscure problem of the physical geography of early geological periods.

Mr Lyell's persevering investigations into the history of the tertiary strata have produced a very remarkable attempt to determine the local origin of the materials of the English tertiaries, and the local seat of the corresponding subterranean disturbances.

The geographical relation of the anticlinal axis of Sussex and Hampshire to the tertiary deposits on either slope, has long fixed the attention of Geologists: it was proved by Dr. Buckland, that the tertiary basins of Hampshire and London were once, at least, partially connected; it was known that the first deposits above the chalk were such as to indicate prolonged action of agitated waters, that the subterranean surface of the chalk was uneven, and that among the tertiary deposits were abundance of pebbles apparently derived from water-rolled chalk flints.

Mr. Lyell supposes that "the chalk of the South-East of England, together with many subjacent rocks, may

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have remained undisturbed till after the commencement of the tertiary period. When at length the chalk was upheaved and exposed to the action of the waves and currents, it was rent and shattered, so that the subjacent secondary strata were exposed at the same time to denudation. The waste of these rocks, composed chiefly of sandstone and clay, supplied materials for the tertiary sands and clays, while the chalk was the source of the flinty shingle, and of the calcareous matter which we find intermixed with the London clay. The tracts now separating the basins of London and Hampshire were those which were first elevated, and which contributed by their gradual decay to the production of the newer strata. These last were accumulated in deep submarine hollows, formed probably by the subsidence of certain parts of the chalk, which sank while the adjoining tracts were rising." (*Principles of Geology*, vol. iii.)

Without following the range of ingenious arguments employed by Mr. Lyell in fortifying his hypothesis, we shall notice the facts which seem most clear in their evidence, and which can be interpreted without theoretical assumptions.

1. It is certain that the Wealden Country, with some other tracts in the South of England, has been uplifted by subterranean movements, independent of that general rise of the whole of the Eastern part of the Island before adverted to. (p. 788.) Whether this was accomplished by one or many successive movements cannot be decided by direct evidence; it would appear, however, that the convulsion was not ended till after the deposition of the whole marine tertiary series.

2. It is undoubted that the upper secondary strata disclosed in the Weald once extended much further towards the central axis, and have been exposed to enormous waste and denudation. There is nothing to negative the opinion adopted by many Geologists, that the whole of the area enclosed between the North and South Downs was once completely covered over by the chalk and the subjacent green sand system; but this admission is not really necessary to the hypothesis.

3. The tertiary basins on the Northern and Southern sides of the axis of elevation of the Weald, contain nearly the same kinds of sedimentary deposits in the same order of succession, so that both of them must certainly have been influenced by the mechanical agency of water, flowing under nearly the same conditions, from the same physical region, or from regions consisting of the same materials equally exposed to aqueous erosion.

4. The materials of the tertiary strata, in the basins of London and Hampshire, are analogous to those which have been removed by denudation of the Weald, since they consist of various coloured sands, which may be imagined to be derived from the green sands and Hastings sands, and of clays which may be supposed to have been furnished by the Gault and Weald clays, and contain pebbles which are allowed to be rolled chalk flints.

If we could venture to add to these statements, that the order of succession among the strata of the tertiary series was exactly that of the successive emergence of the chalk, green sands, Weald clays, and Hastings sands, the hypothesis would stand on much firmer basis than is afforded by the above favourable circumstances. After an impartial consideration of the case, we have not been able to trace such a clear dependence of the successive members of the tertiary series upon the nature of the secondary strata successively wasted, as is implied in the

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hypothesis, that the gradual wasting of the Weald has furnished the materials for the gradual filling up of the basins of London and Hampshire.

Chalk, the secondary stratum liable to be first wasted, and consequently to yield the materials of the lowest tertiaries, has furnished only a mass of flints interspersed among the variegated sands and clays, (with very little calcareous matter,) such as might claim origin from those strata of the Weald which were the last to undergo the influence of litoral agitation. The lower group of the Weald should have left a predominant mass of sands above the other deposits in the tertiary basins.

It may be replied, in favour of the hypothesis, that the fine particles of chalk might remain suspended, or be entirely dissolved in the water, until the period of the formation of the London clay, which is partly calcareous; that the coloured sands associated with flint pebbles were derived from the green and iron sand groups; and that the uppermost deposit of the tertiary groups may have consisted of sand which has since been removed.

Perhaps the most formidable of this class of objections is the total and absolute deficiency of any of the organic remains of the Wealden rocks (except in rolled chalk flints) in any of the tertiary deposits in question. Principal objection to it.

This applies especially to the tumultuous deposits of sand and shells which lie above the chalk; for here surely some of the numerous organic fossils of the green sand system, or some few fragments of the rocks, of the Hastings sands, with plants, shells, or bones, should have been found.

Some recognisable specimens of the shelly marbles of the Weald clay ought, in some one locality or other, to have been discovered in the argillaceous beds which form a predominant feature in the tertiary basins. If it be remembered, that we are here speaking of very contiguous districts; that the distance which the materials can be supposed to have been removed is only a small number of miles; and that it is matter of common observation, that by some currents or other, whether diluvial or alluvial, of transient or prolonged duration, vast quantities of organic remains, separate, or imbedded in recognisable masses of sandstone, limestone, shale, and ironstone, have been drifted fifty or one hundred miles; it must be allowed that the total absence, from the tertiary strata, in all situations yet examined, of any fragments of the Wealden rocks or fossils, is a very serious difficulty to the reception of an hypothesis which derives the one from the other.

#### General View of the State and Prospects of Geology.

A review of the preceding pages offers abundant proof that Geology has escaped from that critical stage through which all Sciences, founded on observation, must pass—the stage of speculation and dogmatism. If it has not yet arrived at the dignity which is conferred upon Inductive Science, by the establishment of very general laws, binding together a mass of dependent phenomena, it is enriched with many valuable generalizations, provided with powerful means of further investigation, and guided by distinct landmarks over a wide field of original discovery. Geology is dissociated from Cosmogony, and we are no longer made to perplex our minds with "thoughts beyond the limits of our frame," no longer required to accept an explanation of natural phenomena, founded on a violation of the laws of Nature. Leaving the impossible problem of the creation and first disposal of the matter of



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the Earth to those who may think there are means of solving it, but ascending beyond the short annals of the human race to the contemplation of the earlier epochs of the World, Geologists endeavour to discover the series of revolutions which have affected the Earth, by deciphering the monuments which they have successively left.

Men may be as soon reclaimed from barbarism, and raised to the summit of civilized excellence, as philosophers induced to abandon the sweet paintings of theory for the hard outlines of fact; and though in the successful career pointed out and followed by the Geological Society of London, the principle of fact before theory has been generally acted upon, it is difficult to repress the impatience which would rather mingle truth and fiction in a bold conjecture, than patiently separate the gold from the dross by the regular process of analysis. The opinion has been expressed by high authority, and seems to be gaining ground, that the time is arrived for the intervention of theory, to arrange the vast mass of facts which at present constitutes positive Geology, and to indicate the lines of further progress toward higher points of knowledge. It is, however, to be supposed, that few will obey this premature call for theory, who are aware of the many unfinished inquiries and vague generalizations which must be settled before even a prudent speculator would venture to commit himself to the tribunal of Inductive Philosophy.

State of geological theory.

We have now assembled many data for a theory; but in the very labour of collecting them, men have gradually acquired what is more valuable, a habit of limited generalization, and of continual appeal to the progress of collateral evidence in unfolding the laws which govern material nature, which at once restrains the presumption of the writer and the credulity of the reader. Under these circumstances the progress of the Science is not doubtful, and all that can be reasonably attempted toward the foundation of a theory of the Earth, is a review of the bearing of the facts already ascertained, on some of the leading problems involved in geological speculations: we shall thus learn what knowledge we have gained; what inferences it will support; how that may be augmented, and these corrected.

#### *Lapse of Time. Geological Chronology.*

All the thoughts of men are so inseparably associated with the idea of succession, that the knowledge of any physical fact is never satisfactory unless the *time* of its occurrence be given. The historical period of an occurrence is determined by reference to other events, whose place in the series of recorded human actions, or natural processes, is known. The chronology or fixing of the year in which any event took place is an admirable contrivance, the fruit of enlarged Science, which has found the means of referring all historical events to an independent and permanent natural scale, the movements in the Solar system. No person proceeds many steps in Geology, without feeling the want of some historical scale of successive phenomena, in which to interpolate new terms of the series; and though this want is to a certain degree generally, and for particular regions of the Globe perfectly, supplied by tables of the superposition of strata, we still find ourselves impelled to attempt the reduction of this historical series to the independent scale of chronology.

This difficult problem has never been fairly entered

upon, except in the particular case of the diluvial and alluvial deposits. Those who admit the identity of the diluvial currents of Geologists and the Noachian flood, and suppose, with Cuvier and De Luc, that this was "the last great revolution affecting our Globe," may be expected to feel some anxiety as to the number of years which, on natural, that is to say, geological evidence, can be reasonably supposed to have elapsed since that event. In such inquiries the growth of the deltas of the Nile, the Po, and other rivers, the movement of the sands of Libya, the excavation of river-courses, may all be employed according to the views of the writer. Always it is to be remembered, these calculations admit as a principle the uniformity of natural superficial agencies since the diluvial period, and that period is geologically defined with more or less certainty; from such data consistent results seem attainable. There are, however, difficulties in estimating the amount of mechanical effect performed, not easily overcome. In the case of a delta, the materials may have fallen into water of unequal or unknown depth, and have been exposed to waste by currents of variable force; the movement of sands must be yet more capricious; the time employed in the recession of the falls of the Niagara from Lake Ontario to Lake Erie, has been estimated by Mr. Lyell at 10,000 years, by Mr. Fairholme at 5000; five or six thousand years is the vague conjecture, rather than conclusion, of Cuvier, of the time elapsed since the "last grand catastrophe;" and in general it must be owned that the methods of arriving at these conclusions have very little of accuracy to recommend them.

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Those Geologists who admit the excavation of valleys by a force of water greater than what now passes down them, may take the date of the denudation of these as an era, and compute the time elapsed in the subsequent excavation of the river bed, in the partial or complete filling up with sediment of lakes along its course, and in the retrocession of waterfalls along the main or branch streams. Few persons, however, who value an arithmetical result for its precision, will proceed to the calculation without more information of the *rate* of these operations than is at present attained.

The fossil elephant, and other animals whose remains lie buried in gravel and other deposits called diluvial, belonged to a system of organic life, which, for some limited period prior to and during the era of those deposits, was established over a large part of the surface of the Northern hemisphere. This is termed by many Geologists the antediluvial period; some intending by this, nothing more than to mark its relation to the era of the "diluvial" currents, thus adopting the term from comparison with Scripture History. This is, properly, a terrestrial period, and we have shown the difficulty of defining its limits towards the tertiary period, which is, properly, a marine period. (p. 671.) The lacustrine tertiaries here become almost our only safe guides, and they teach us that during the tertiary period an earlier group of extinct animals, the palæotheria and their congeners, inhabited the same tracts of the Globe, as those which afterwards nourished the mammoth and mastodon. We are absolutely without any means of estimating in years the length of the interval between the era of the palæotheria buried in the Paris basin, and that of the elephants which are entombed in gravel deposits. The small extent of alluvial and lacustrine deposits of this period may perhaps justify a conjecture that it was of short duration, as compared to the postdiluvial period; but this view must

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not be adopted by those who attribute to the diluvial currents the excavations of valleys and other extensive alterations of the surface; because such a deluge would sweep away most of the traces of antediluvian lakes.

If the difficulties experienced in attempting to chronologize the terrestrial phenomena of the later geological periods have been sufficient to deter nearly all prudent and exact writers from venturing to give more than an illustration of the kind of reasoning to be employed, it is no wonder that for the long series of successive marine strata the attempt has been almost absolutely abandoned. It is doubtful whether we ever shall arrive at more than plausible inferences concerning the *time* elapsed in the production of the stratified rocks; yet as the consideration of this subject can be prosecuted in a strictly philosophical spirit, by the help of several satisfactory analogies, and as at all events the historical succession of the phenomena is either perfectly known or capable of becoming so, it appears an equally useful inquiry as that relating to the subsequent terrestrial periods.

Old stratified deposits

To determine the length of years required for the deposition of all the stratified rocks under the circumstances in which they are observed, requires a knowledge of the number of repetitions of similar phenomena, and of the rate of their occurrence. In the Geology of stratified rocks several independent series of phenomena occur, each of which may be subjected to this examination. Of these we may notice:—

1. The mechanical deposition of sands, clays, conglomerates, &c.
2. The chemical deposition of limestones.
3. The periodical alternations of the laminæ or strata of clay, sand, limestone, &c.
4. The growth and decay of organic beings then living in the sea.
5. The successions of races of organic beings in the same parts of the Ocean.
6. The succession of convulsions.
7. The alternation of marine and fresh-water productions.
8. The alternation of marine and igneous products.
9. The metamorphism of rocks, fossils, &c.

1. Mechanical deposits of sand, clay, &c. take place only in consequence of degradation or waste of some region of the Globe, followed by a removal of the materials to some place of comparative tranquillity. Intermitting actions of this kind usually produce laminated deposits, and if the materials be of different kinds these may alternate in the sediment. In some valleys, every inundation leaves a thin layer of sediment; the number of inundations might thus be counted since any given date, and the number of years nearly ascertained. Analogous effects happen along those coasts where the tides deposit sediment; we see the same effects in many of the sandstone and clay strata which were accumulated in estuaries.

Some of the flagstones of the coal measures are composed of frequent alternations of rolled grains of felspar, quartz, and mica, which may be estimated to occupy not more than one-twentieth of an inch in thickness. Taking the thickness of the rock at 40 feet, we shall have 9600 layers, each of which marks an *interrupted action*. Let this be supposed to be the tide, allow that every tide deposited one layer, equal to about 700 per annum; this will occupy 13½ years. As far as we

can ascertain, the other sandstones of the coal tract were accumulated in the same manner, though only a few of them are micaceous enough to show this minute lamination. The thickness of the Yorkshire coal measures is about 3000 feet, half of this may be considered as sandstone equal to 1500 feet; which, according to the above calculation, might be deposited in about 500 years. If we suppose the accumulation of the alternating clays to have been at the same rate, (there is good reason to admit this,) the whole period occupied in the deposition of the coal measures would be 1000 years.

It is perhaps unnecessary to say, that the assumption of each lamina marking the action of one tide is perfectly gratuitous, and has been adopted merely to give a specimen of the mode of calculation which must be employed if we wish to state the probable extent in years of a given geological period. Conglomerate rocks present a most convincing proof of the considerable periods which sometimes intervened between the deposition of two stratified rocks in contact and immediately succeeding one another. These rocks of turbulent origin are locally distributed, so as to be in some parts enormously thick, and in other places almost or entirely deficient. The old red sandstone conglomerate, for example, usually separates by a great thickness the greywacke slates from the superincumbent carboniferous limestone. In Herefordshire and Radnorshire, this series of red sandstones and conglomerates is many thousand feet thick, but in the greater part of the Cumbrian mountain tract it is absent, and the limestone and slate are in contact. In this case, it would be a great error to suppose the deposition of the limestone to have been immediately consequent on that of the slate. In fact, that very district gives proof that a period of violent watery tumult intervened, during which the slate rocks were broken up and rolled to pebbles, and reconsolidated into a thick conglomerate. The rate of this process can only be conjectured, by comparison with the production of pebbles by the diurnal processes of tides, rivers, and local inundations. When, as in the Rigi, we find rolled masses of conglomerate containing rolled pebbles; in the old red conglomerate of Cumberland masses of the preconsolidated slate; in the new red conglomerate of Westmoreland fragments of the mountain limestone with organic remains which have undergone *their usual chemical conversion*; enough is known to prove, to a mind not wholly blinded by false views of Science, that the monuments left for Geology to decipher carry back the History of the Earth to periods when man and his works existed only in the long foreknowledge of his Maker.

2. Chemical deposits of limestone.—It is difficult to fix upon any method of estimating in years the time required for the deposition of a given mass of limestone. It is useless to refer to instances of the production of limestone from springs, in fresh-water lakes, in estuaries or coral reefs, unless the circumstances under which the older calcareous deposits were made are similar, a case seldom to be proved. The following process, founded on the statements in p. 551, appears the least objectionable.

It is certain that while the sandstones, shales, coals, and thin oolitic limestones of the North York moors were deposited upon the lias, a deposit almost wholly calcareous was occasioned near Bath. The whole time consumed was the same in each locality; we may therefore perhaps infer the comparative rate of deposition of the oolite and the sandstones. The total thickness of the mass in Yorkshire is about 750 feet, of which about 20

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may be called limestone; of that near Bath 480, of which nearly half is sand and clay with calcareous matter interspersed. Hence we have the proportion of three feet of sandstone deposited in the same time as one of limestone.

Another instance is afforded by comparing the sections of the lower carboniferous limestone, in Derbyshire and in Tynedale. In the former tract we may take 750 feet as the thickness of limestone, with no admixture of sands or clays; in the latter, the contemporaneous strata are at least 1750 feet thick, and contain 367 feet of limestone, and 1283 feet of sands and clays, &c.; consequently, 363 of limestone correspond in time to 1283 of sands, clays, and coal, or 1 to 3.3.

### 3. Alternation of chemical and sedimentary deposits.—

There is undoubtedly a periodicity in these alternations, but we are not yet in a state to draw any inferences, as to the cause of the recurrences, much less as to the length of their periods.

Organic remains.

4. Imbedded organic remains.—In viewing the shells distributed in rocks, we sometimes perceive, amongst a large collection of them from a given stratum, a complete series of forms from the youngest to the full grown shell; and this may be a means of calculating the lapse of time during the accumulation of a given thickness of rock more exactly than by any other. A thickness of calcareous shale, not exceeding one foot in the Yorkshire coal field, holds individuals of ammonites *Lasteri* of every magnitude between a pin's head and an orange; it is not to be doubted that they lived where they are found; and as not one example of this species is known in any other stratum in the neighbourhood, it seems correct to admit that, during the deposition of that small mass of shale, so much time elapsed as to allow of the growth to full maturity of a long-lived cephalopode. The only other supposition which can be entertained, is that they were introduced alive by a transient irruption of the sea into a fresh-water basin, and there quickly entombed.

It is to be regretted that the age of shells has been very little inquired into among collectors. Both conchifera and mollusca are probably, in general, long-lived animals.

The immense number of shells occasionally buried in a rock is sometimes appealed to as a proof of the length of time consumed in its production; but this is a very unsatisfactory argument. Those who have witnessed the amazing increase of *cyclus rivicola* in the canal near Leeds, or of unioes and anodontes in many sluggish rivers near the tideway, have walked among the numerous shells on the coast of Ayrshire, or the crowds of tellinæ thrown upon the Fife sands by a single tide, will not permit to Geologists the use of such a fallacious inference. This immense abundance of fossils is often a local phenomenon in the rock, and one which, when better understood, will aid materially our conceptions of the agencies which were concerned in its accumulation.

The nearly vertical position of certain fossil plants, a phenomenon by no means rare among sandstone rocks, affords good ground for caution in assigning very great extension of years to geological periods. The stems of *equiseta* in sandstone of the oolitic era, (page 625,) of *sigillaria* in sandstone of the coal series, (page 596,) of *dictyodendron* wood in limestone of the Isle of Purbeck, seem to teach us in plain terms that the accumulation of these rocks was not of that slow and insensible kind which is often attributed to them. Whether we suppose them to be in their place of growth, or to

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have been swept down to their present situations by land floods, the result as to our present argument is the same; the accumulation of transported sediment must have been so rapid as to prevent the decomposition of the cortical portions of the plants, the wearing away of the superficial structure, or the bending of the stem beneath currents of water. No one doubts that the bed of stone three feet thick, which encloses *equisetum columnare* at High Whitby, was laid by a single inundation; we will suppose it an annual occurrence; the other sandstones and shales of this series must have the same rate of origin ascribed to them; this would give for the formation of the oolitic sandstones and shales in the North York moors a period of 150 years. About the same, or a slower rate of formation, may be supposed for the case of *sigillaria* in the coal sandstones of Yorkshire; for these stems, when above two or three feet long and nearly vertical, pass through more than one, sometimes four or five beds of stone. (Altofts near Wakefield.)

5. Successions of races of organic beings in the same parts of the Ocean.—The succession of different races of organic beings in the same parts of the Ocean, is one of the leading facts which speak the most impressive, though not the most exact, language on the subject of the long duration of geological periods. For, whether we consider those cases in which the extinction of old and the introduction of new species was gradual, or others when the changes were sudden and complete, nothing that we know of the actual constitution of Nature will justify us in admitting that these revolutions in the animal world followed quickly one after another. We are impelled to conclude that, for the existence of any given race, consisting of thousands of individuals of many hundred species, imbedded in many different kinds of rock, in distinguishable groups according to their habits of life, a long time must be allowed, or else the whole constitution of Nature was in a state of forced acceleration, so that the work of ages was crowded into years. Whether we suppose that new species were contemporaneously created in all the situations where they lived and died, or distributed from one local origin over the sea, or transported by currents from other oceanic centres of life, no one who considers the stability of the actual system of watery life, will be easily persuaded to believe that these prodigious changes were operated over a large part of the Globe in times that can be included within such narrow limits as those of human experience. Yet who will venture to translate the vague and almost poetical visions of long duration, which the contemplation of many repetitions of these local revivals of Nature so powerfully awakens, into the language of chronology? It is evident that the day is not yet arrived, or rather it is gone by, for dogmatizing about the antiquity of the crust of the Globe.

6. The successions of convulsions in the same physical region may be very properly mentioned as a vague indication of the lengths of geological periods; but cannot at present be employed in a more exact manner to determine their duration.

7. The alternation of marine and fresh-water products is another of those grand phenomena, which, whether rightly or not, is sure to make a deep impression on the mind; though the rarity of the case, and our ignorance of the principal efficient circumstances, must wholly exclude it from among the data for accurate calculation of geological time.

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8. The same may be said of the alternation of aqueous and igneous products.

9. The metamorphism of rocks, &c., in consequence of the local or general effect of heat, may possibly one day be sufficiently understood to permit some attempt towards determining the intensity and rate of the communication of heat, and thus more or less directly bear upon the question of time. The chemical changes of organic remains are evidently less related to time than to other circumstances, such as, the original nature of the body, the sort of substance in which it is imbedded, and proximity to sources of mineral impregnation, whether by aqueous or igneous solution, or electrical transfer of solid ingredients.

#### *Successive Conditions of the Globe.*

The object of geological researches has been till lately very little understood by those not directly conversant with the subject; and even professed Geologists do not always restrict their inquiries within just bounds. It is difficult for a speculator to believe that Geology may become a very important branch of natural Science, though it should wholly disclaim the investigation of problems concerning the creation or concentration of the matter of the Globe, or the establishment of the laws of the universe. To know the successive changes which the Globe has undergone, and thus to trace a retrospective outline of its successive conditions, is actually attempted by Geology; but the very processes employed in this enterprise are founded upon the recognition of the existing laws of Nature, and altogether exclude the popular notion of a chaos, and the philosophical hypothesis of a solid Globe condensing from an atmospheric expansion.

Undoubtedly the progress of legitimate Geology teaches us that the same laws of Nature have operated on this Globe under very different circumstances, as to temperature, relation of land and sea, animal and vegetable life, and many other things; and it is become a proper problem for Geology to discover these circumstances. In this point of view, the reflections of Leibnitz, and the mathematical labours of Laplace and the astronomers, become of great value, since they help to fix conspicuous landmarks for the guidance of the surveyors in this large field of Science; but let no one delude himself with the notion of discovering, by geological processes, the emerging of the harmoniously adjusted terraqueous Globe from a former state of chaos. It is certainly not a philosophical, and surely cannot be thought a religious notion, that man shall ever discover among the works of God, the traces of a period when his divine attributes were first awakened to rescue his creation from anarchy. Geology takes for granted the existence and collection of the matter of the Globe, with its supernatant Ocean, and its enveloping atmosphere. Except in the degree of influence which circumstances permit them to exert, it takes for granted the uniformity of action of all material causes. The investigation of miracles can never be admitted into natural Science.

The dimensions of the Globe have remained constant since the days of Hipparchus; (born 160 B.C.) for Laplace has shown that the length of the day has not sensibly varied since that time, which must have happened if the diameter had perceptibly changed: if the Globe had contracted, the diurnal period would have been shortened, and *vice versa*.

This is usually considered a very formidable argu-

ment against the doctrine of internal heat, and its corollary, secular refrigeration and contraction, to which theorists have very freely resorted; as the prolific source of all subterranean movements, changes of superficial temperature, elevation of continents, volcanic eruptions, injection of igneous rocks, mineral veins, &c. Fourier's researches, however, into the mathematical theory of heat, show that, under the conditions of sensible constancy of dimension, and variation of superficial temperature according to solar influence, we are at liberty to suppose the existence of deep seated heat of any intensity, provided there be direct indications of corresponding augmentation of sensible temperature below, a certain depth. Such indications, it is very generally allowed, are presented by the observations in mines and collieries in Europe, Asia, and America.

With regard to secular refrigeration, the experience of two thousand years undoubtedly shows that its effect in contracting the Earth's diameter has been for that period insensible; but, first, it must be observed, that the hypothesis supposes the effect of refrigeration to be a contraction of an internal nucleus, and a consequent separation between it and the solid crust, which continually increases until the crust is broken by a convulsive collapse; secondly, it is sufficiently evident that, by the accumulation of nonconducting materials over a source of heat, the diminution of this heat must become continually more and more slow, so as at last to be insensible even in very long periods. If, then, it should appear that the leading phenomena of the ancient History of the Earth can be well explained by help of these suppositions, there is nothing in the mathematical theory to prevent their provisional adoption, on the basis, not unfrequently employed in Natural Philosophy, that they serve to explain many phenomena.

It is by no means necessary to couple with the hypothesis of internal heat, the doctrine that volcanic action arises from this cause only: the various chemical characteristics of volcanic action must be examined upon their own evidence; and it does not appear that the theory of volcanic operations, advocated in a former part of the Essay, is at all deprived of its applicability, or rendered superfluous, by admitting the existence of intense internal heat. On the contrary, under the influence of a high temperature, the admission of oxygen and water would still produce upon the fluid metalloids and metals the effects usually ascribed to such a cause, and perhaps more easily than if they were solid, and the results would still be proportioned to the circumstances of the locality.

These remarks are not introduced for the purpose of advocating the hypothesis in question, but to rescue those who have adopted it, and by it endeavoured to illuminate some of the darkest pages of Geology, from the imputation of invoking causes which chemical and mathematical researches concurred in disproving.

The moderation which Geologists were so slow to learn, has prevented them from reviving the ancient speculation which ascribed the leading phenomena of Geology to an extensive shifting of the Earth's axis, and consequent displacement of the Ocean. To be consistent, we must suppose this mighty operation to have been many times repeated before the occurrence of the Deluge which it was invented to explain. Perhaps the probability that every part of the Globe equally requires this displacement of the axis, but requires it in different directions at the same time, may be sufficient to

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of geolo-  
gical in-  
quiry.Volcanic  
action.Displace-  
ment of the  
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prevent its resurrection. It is too much, however, to treat it as an absurdity, merely upon the ground that the shells of equal density within the Globe have their axes, at the present moment, nearly coincident with those of the surface; for Sir J. Herschel has expressed the opinion that the spheroidal figure of the Earth might be acquired during rotation though its parts were not fluid.

But, as Mr. Greenough has observed, "be the cause what it may, the fact is certain, that the temperature of the crust of the Earth was, higher when the coal measures were deposited than now, and we have reason to think it was still higher at antecedent periods. That a considerable degree of heat still exists, either partially or generally, at no great distance from the surface, appears from thermal springs and volcanoes." (*Geological Society's Proceedings*, 1834.)

Origin of  
terrestrial  
organic life.

In accordance with this view is the common opinion, that geological inquiries have discovered traces of a period in the History of the Globe, when neither animal nor vegetable life was established upon it. This opinion, ably expressed by Dr. Buckland in his *Vindiciæ Geologicæ*, is chiefly supported by the facts observed in studying the primary and transition strata. The view of the subject which is most consonant to the course of inferences adopted in this Treatise, has been already sufficiently expressed in the review of the primary strata, (p 570, 571.)

Whatever may be truth on this point, it is certain that the successive systems of organic life, both terrestrial and aquatic, animal and vegetable, show the same general principles and relations as that to which we belong. Geology has disclosed various and remarkable animals, not paralleled in existing nature, and plants of singular forms, but nothing which deviates from those general laws of structure and function which govern the actual organic creation. The plants and animals of different geological periods do not differ more from one another, than those in opposite climates, or even distant localities at present. There is even to be observed among the several successive systems of organic remains some real analogy to existing local Faunas and Floras: theoolitic fossils have, perhaps, a greater resemblance, for instance, to the living productions of Australia and the Indian Islands, than to those of any other situation; while the plants and unioles of the Northern English coal tracts remind us of the physical characters of the American continent rivers and islands.

Periods of  
convulsion  
and repose.

There is, perhaps, no point of theoretical Geology more certainly established than that, in any given small area of the surface of the Globe, long periods of ordinary action of natural causes have been several times interrupted by epochs of extraordinary disturbance; that the relation of the level of sea and land has remained for a long time the same, or very gradually changed, and afterwards been altered by internal convulsions. It is also admitted that this law has an extensive though then less exact application; that the periods of ordinary and crises of extraordinary action were respectively contemporaneous over very large regions of the Globe, and even with respect to some of the cases admit of general application. It appears, also, that the nature of the strata deposited differs more or less according to the several successive periods, and that the races of organic remains, in several important cases, are subject to contemporaneous crises. On this evidence, joined to some theoretical considerations, is founded the modern admission of the doctrine of

alternating periods of convulsion and repose; a doctrine which was held by ancient Philosophers, revived by Leibnitz and Hutton, and illustrated by Cuvier and De Beaumont. Perhaps this view of the subject was never more clearly expressed than by Leibnitz, whose just sense of the philosophy of Geology has been lately placed in a strong light by Mr. Conybeare. His view is, that the powerful agencies exerted in displacing and altering the solid crust which gradually thickened over the ignited nucleus, have many times renewed the face of the young Globe by the eruption of concreted igneous rocks from below, and the deposition of stratified rocks by water above; and that the Globe was, by these processes, more and more diversified with mountains and valleys, and subjected to various physical conditions; *donec quiescentibus causis, atque æquilibratis, consistentior emergeret rerum status.*

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Mr. Lyell's pictures of the successive conditions of the Globe are all drawn to one scale, from the unvarying standard of its present state; his hypothesis admits local alternations of ordinary and critical action, but denies any thing like a general paroxysmal effort of natural agents; nor is there, between the ordinary and critical stages of his processes, any conspicuous difference. The principle of his system is, that the disturbing internal forces exert themselves in irregular succession beneath all the points of the surface of the Globe; and that the ordinary chemical and mechanical agencies of Nature are thus modified in their intensity, and diversified in their effects, and applied to produce an endless series of destructions and renovations, which, upon the whole, compensate one another continually.

In this system, the postulate required is *unlimited duration*; in the other, a varying momentum of natural agencies according to *difference of condition*: the one is a system of continual, the other of intermittent compensation. Nature offers to our view examples of both these cases, and on a large scale; it is therefore very unwise to assume one or the other on account of our notion of its greater probability; we must see which of the systems finds support from the facts of the case. It has been already seen that our *proofs* of the periods of time elapsed are neither clear, satisfactory, nor complete; much of the evidence on this subject is in unknown terms; but estimates derived from probable views of the mechanical composition and organic contents of the strata, do not appear to warrant the postulate of unlimited duration. (See p. 795, 796.)

On the contrary, be the duration of geological periods what they may, it is clear that the Earth has successively undergone great physical changes; terrestrial agencies must therefore have operated upon it, with a corresponding variation of effect; one of these changes of condition, that of superficial temperature, is not explicable by any of the known periodical inequalities of the Solar system, but seems in harmony with the general theory of internal heat, gradually becoming less and less sensible as the external crust thickened, and the surface of the Globe approached to a state of equilibrium.

#### *Successive Conditions of the Materials of the Crust of the Globe.*

The question of the origin or first condition of the elementary ingredients of earthy and metallic substances, if capable of solution, must be referred to another Science; but inquiries into the successive conditions of

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the mineral substances which appear in the crust of the Globe, is one which, in some shape or other, must be often proposed to a Geologist. It is difficult to stop at the recognition of the igneous origin of some rocks, the aqueous production of others; we cannot avoid examining, whether any evidence can be found for determining a prior condition of the substances contained in these rocks. Facts of great importance here come before us; we see examples of new rocks produced by heat from aqueous deposits, and sedimentary aggregates of the disintegrated ingredients of volcanic and plutonic masses. The deposition of limestone offers very remarkable variations, and it is impossible to consider the composition of the minerals in crystallized rocks, without feeling that the resources of Chemistry are or may become capable of advancing us one more step in the analysis of the series of conditions through which the solid ingredients of the Globe have passed.

The time is not long gone by when Werner, who, with far less moderation than Dr. Hutton, wished to begin at the beginning, could find thousands of followers in the startling dogma, that all the rocks observed near the surface of the Earth, were deposited from one chaotic fluid, which first permitted the crystallization of granitic and other rocks, and afterwards produced the secondary sandstones, shales, and limestones. It is possible that even yet there may be persons who can believe that these secondary sandstones were produced by a chemical decomposition of the ancient Ocean; which, to answer all the unreasonable demands upon its powers, must have been endowed with more than the creative energy of a Brahmā, and capable of surmounting every chemical and mechanical impossibility—of crystallizing into sand, condensing into limestone, and subliming into metal!

Leibnitz, and a large portion of modern Geologists, also attempt to fix something like a beginning to their system, a point of geological time when the change from a fluid to a solidified surface permitted the development of that series of intermitting igneous and aqueous actions, which has brought the Globe by many revolutions to its present state of comparative repose. The followers of Dr. Hutton see no such commencement to their series of terraqueous effects; they find no physical traces of a beginning, nor any change of operation which should give the prospect of an end of this series of effects proportioned to the time elapsed. Yet, as one hypothesis admits locally, periodically, and repeatedly, what the other supposes to have happened generally and in one succession, there is no necessary disagreement in the interpretation of particular cases. This is not always remembered by those who engage in the controversy concerning the uniformity of natural effects.

Successive  
conditions of  
certain sub-  
stances.

If we trace back the history of the materials of the sedimentary sands and clays now in process of formation at the mouths of rivers, along the sea-coasts, and in other situations, we shall find that these materials are often derived from ancient superficial deposits left by local extensive floods; examination proves that the materials of these deposits were often obtained by the violent breaking up and attrition of far more ancient previously solidified strata; in several instances it is manifest that these are nothing else than the oceanic accumulations derived from disintegrated primary strata, or of disintegrated pyrogenous rocks.

As an example, we shall quote a well-ascertained series of facts, which leave no doubt of the many changes

of condition through which the granular ingredients of modern sedimentary deposits have passed. 1. The Ouse, Trent, and other great rivers connected with the Humber, are so filled with the finer parts of the sediments which fall into the sea along the wasting cliffs of Holderness, that their flood-waters, when introduced to the lower ground along their banks, deposit a great thickness of valuable soil. The sandy and coarser parts of the sediment are collected in various irregular positions in the Humber and along the coast, and the pebbles remain on the beach, or follow its descent for a small distance into the sea. 2. The diluvial cliffs, which by their destruction afford this rich supply of fertile warp and sterile sand, contain fragments of all the rocks in North-Western Yorkshire, that is to say, basalt, limestone of many kinds, cherts, sandstones, fine-grained and coarse-grained millstone grit, shales, ironstones, and coal; fragments of granite, hypersthene rock, and greywacke slates from Cumbria; all imbedded in a vast thickness of sands and clays composed of the same comminuted materials. 3. The millstone grit, fragments of which occur in this diluvial mass, is a compound of felspar, quartz, and mica, with occasional admixtures of other substances. These minerals are easily recognised as *rolled and water-worn masses*, derived from porphyritic granite, gneiss, and other such rocks. The felspar is always perfectly crystallized within, but the external surface is water-worn; the mica has lost its angles; and the quartz fragments are only in the state of large grained sand. Plainer proof of mechanical aggregation of ingredients which once composed a crystalline felspathic rock, cannot be desired; many such instances are known, and the inference is generally allowed.

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As far as the results of a careful examination of ordinary sandstones can be trusted, there is no reason to refuse to them, as a general rule, the same kind of origin as to coarse millstone grit. Most of them have the same ingredients, though it frequently happens that the felspar is in a state of decomposition. Shales and clays are to sandstones what the fine warp in the water of the Humber is to the sands in its channel; we may then venture, in a moderate spirit of generalization, to assume, that sedimentary sandstones and shales have originated in the mechanical action of water upon the disintegrated granular ingredients of pyrogenous rocks.

Extension  
of this in-  
ference.

Any one who has sufficiently observed the varieties of sandstones and shales on the one hand, and of stratified primary rocks on the other, and considered the nature and amount of the changes produced upon them respectively by heat; or properly weighed the observations and reasonings of Macculloch; will have no difficulty in admitting the views as to the origin of the latter class of strata advocated in former parts of this Essay. We are therefore conducted, apparently by a legitimate process of induction, to the conclusion that all the stratified rocks, limestone and some particular strata excepted, are derived primarily from the decomposing agencies of Nature operating upon pyrogenous rocks; and we thus find a natural limit to the series of conditions through which these materials have passed. This conclusion, though perhaps less distinctly stated, is essentially recognised in modern geological systems and is felt to be substantially true, though it still leaves many things to be explained.

An inquiry as to the origin of the vast masses of stratified limestone, is a subject of considerable difficulty. In a great majority of instances the limestone

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formed at the present day is the result of chemical forces, and the same was probably the case in earlier periods. In particular instances, calcareous deposits have partially or wholly a mechanical origin; as when a stream brings down the waste of a chalky or oolitic district, and deposits the sediment in a lake; or when the currents of the Ocean drift shells and other marine exuviae and lodge them in the midst of coral reefs. Observers of the growth of coral islands have detected several facts as to the intermixture of decomposed fragmentary and entire calcareous marine exuviae with coral rock, which seem to render not improbable the opinion of Geologists, that some of the older secondary and transition limestones are in places only magnificent coral reefs.

Origin of  
limestone.

Perhaps nowhere has the mechanical origin of limestone been assumed to a greater extent than in the Huttonian system of Geology; for it seems to be an essential part of that system, that the stratified limestones are nothing else than triturated shells and other calcareous exuviae. By those who adopt this view, chalk, the least compacted kind of limestone, is usually taken as an example. It is sometimes difficult to avoid imagining that the powdery magnesian limestone is a recomposed rock, derived from the ruins of magnesian beds of carboniferous limestone. But this cannot be a true account of the matter; for, 1. there ought to be far less *magnesia* in the compound. 2. This is in some instances an atomic combination of carbonate of magnesia and carbonate of lime. 3. This limestone is often really a granularly crystalline rock, (like the older magnesian beds of mountain limestone,) and seldom appears to justify the least suspicion of the mechanical agency of water.

But nothing is more certain than that of all the strata yet discovered, limestone is exactly that which, by the regularity and continuity of its beds, by the extreme perfection of its organic contents, and by the absence of proofs of mechanical action, gives most completely the notion of a chemical precipitate. It appears sufficiently probable, in several instances, that the quantity of limestone deposited in a given geological period was least towards the shores, and greatest towards the deep sea, exactly the reverse of what happens with the mechanical deposits of sandstone and shale; it may therefore be viewed as an oceanic deposit, resulting from a decomposition of sea water, aided in many instances to

a wonderful extent by the vital products of zoophytic, echinodermatous, and molluscous animals. According to this view, it is easy to understand the repeated production of limestones of the same mineral character at different periods; nor need we feel surprised that, occasionally, limestones of the same age differ in properties.

However, all these views end at last in one, viz. that the earliest condition which we can assign to the carbonate of lime, is that of extrication from some solution of lime in water, by chemical or vital processes. And here, perhaps, it will be wisdom to pause, for though some have ventured to imagine that the lime might be derived from the decomposition of particular ingredients in primary igneous rocks, and others may suppose that the Ocean would more directly obtain this with other ingredients from the oxidized fluid nucleus of the Globe, such speculations are beyond the pale of Inductive Geology, and involve too many hazardous assumptions to be at present worthy of the notice of other Sciences.

The general tendency of geological reasoning is to establish the inference, that a large portion of the stratified deposits have been formed from the wasted ingredients of pyrogenous rocks: all the phenomena of volcanoes and ancient igneous eruptions prove that *locally* stratified deposits are reconvertible to crystalline rocks by the force of heat, and very *generally* alterable in character so as to approximate to the actual products of heat. Mr. Lyell puts this to the extreme, and supposes that the calorific energy of the interior of the Earth is constantly acting, so as to reconvert sedimentary into crystalline aggregates, *equal quantities in equal times*, and thus to maintain a perpetual equilibrium between the liquefying internal and the solidifying external agencies of the Globe. This speculation is much too poetical to be examined according to the dry rules of the Baconian Philosophy: if the heat expended in this operation be obtained from chemical processes, these must gradually tend towards equilibrium; if from a general internal reservoir of caloric, that reservoir must become less and less prompt in supplying the incessant demand: either of these effects operating through *indefinite time* must cause the gradual refrigeration of the surface of the Globe, a consequence not favourable to the hypothesis of the uniformity and continual compensation of the effects of internal and external terrestrial agencies.

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result

## Reference to Plates II. and III. of Organic Remains.

## PLATE 2.

## TERTIARY SYSTEM.

1. *Voluta dubia*. Brander.
2. *Dentalium striatum*. Sow.
3. *Venericardia planicosta*. Sow.
4. *Fusus bulliformis*. Sow.
5. *Emarginata reticulata*. Sow.
6. *Cytherea lentiformis*. Sow.
7. *Turbo littoreus*. Sow.
8. *Scularia foliacea*. Sow.
9. *Murex tubifer*. Sow.
10. *Fusus contrarius*. Sow.
11. *Cyprina Avellana*. Sow.
12. *Trochus agglutinans*. Brander.
13. *Pleurotoma exorta*. Sow.

## CRETACEOUS SYSTEM.

12. *Pecten quinquecostatus*. Sow.
14. *Aplocrinus ellipticus*. Mill.
15. *Spongia cribrosa*. Phil.
16. *Marsupites Milleri*. Mantell.
17. *Inoceramus sulcatus*. Sow.
18. *Trigonia aliformis*. Sow.
19. *Catillus Brongniarti*. Sow. and Brong.
20. *Ammonites varians*. Sow.
21. *Plagiostoma spinosum*. Sow.
22. *Heimerites mucronatus*. Cuv. and Brong.
23. *Spatangus Cur-anquium*. Cuv. and Brong.
24. *Scaphites costatus*. Mantell.

## OOLITIC SYSTEM

25. *Trigonia costata*. Sow.
26. *Vertebra of Plesiosaurus*.
27. *Claris intermedia*. Fleming.
28. *Clypeus clinicalaris*. Lidge.
29. *Vertebra of Ichthyosaurus communis*. Conybe.
30. *Ammonites Walcottii*. Sow.
31. *Photastonyia Marchisoni*. Sow.
32. End of the Upper Jaw of Crocodile
33. *Mya V. scripta*. Sow.
34. *Gryphaea incurva*. Sow.
35. *Ammonites Galloviensis*. Sow.

## PLATE 3.

## SALIFEROUS SYSTEM.

1. *Producta horrida*. Sow.
2. *Retepora virgulacea*. Phil.
3. *Terebratula globulina*. Phil. MS.
4. *Terebratula*.
5. *Pecten radiata*. Phil. MS.
6. a. *Avicula gryphaeoides*. Sedg.
- b. Dorsal view of the same.
7. *Azinus obscurus*. Sow.
8. *Retepora Suetacea*. Phil.
9. *Palaeothriassum macrocephalum*. Sedg.

## CARBONIFEROUS SYSTEM.

10. *Platycrinus levii*. Mill.
11. *Actinocrinus 30 dactylus*. Mill.

12. *Pentremites ellipticus*. Sow.
13. *Pleurothyridus minax*. Phil. MS. (New genus)
14. *Orthoceras Breynti*. Sow.
15. *Spirifera stylata*. Sow.
16. *Producta punctata*. Sow.
17. *Ammonites Listeri*. Sow.
18. *Ammonites striatus*. Sow.
19. *Bellerophon blucius*. Sow.
20. *Pleurotomaria*, (*Helix carinata*? Sow.) colour stripes remaining.
21. *Euomphalus pentangulus*. Sow.
22. *Syringopora fuciculata*. Phil. MS.
23. *Favosites capillaris*. Phil. MS.
24. *Asaphus gemmuliferus*. Phil. MS. magnified twice.
25. *Terebratula acuminata*. Sow.

## PRIMARY SYSTEM.

26. *Euomphalus diacora*. Sow.
27. *Producta depressa*. Sow.
- Dorsal view of the lower valve.
28. *Terebratula affinis*. Sow.
29. *Calymene Blumenbachii*. Brong.
30. *Asaphus De Buchii*. Brong.
31. *Pentamerus Knightii*. Sow.
32. *Orthoceras annulatum*. Sow.
33. *Orthoceras pyritiforme*. Sow.
34. *Cyathophyllum hexagonum*. Goldf.
35. *Catenipora labyrinthica*. Goldf.
36. *Astraea porpa*. Goldf.

# INDEX TO GEOLOGY.

Index to  
Geology.

To facilitate the study of the Article Geology, and to make known the nature and the views advanced in it, is the object of the following abstract. The subjects discussed in Geological Treatises of modern date are, of necessity, extremely varied, for the Natural History of the Earth is too vast and diversified a problem not to require continual reference to the truths of collateral Science. In the present Treatise, a great portion of the inferences and general reasoning is, indeed, collected into a separate and final chapter; yet, in many instances, the inferences from phenomena are introduced after the description of these, especially when it seemed likely to render the succeeding descriptions more clear. The following summary will explain the distribution of subjects throughout the four Chapters of the Treatise, and serve as a General Index, permitting, at the same time, a connected view of the Science.

## CHAPTER I.

### PROGRESS AND PRINCIPLES OF THE SCIENCE.

#### Progress of the Science.

Page

- 529 *Definition*, with reasons for its wide limits.  
*Speculative Geology* gradually changing, with the progress of Physical Science, into  
 530 *Inductive Geology*, which, in different Countries, was based on different data. *Laster* originated the *agricultural school of Geology*, which has nowhere made progress commensurate with its importance.  
*Mining knowledge* was the basis of another school brought to eminence in Germany under the auspices of *Werner*, who claims the merit of introducing, more clearly than had been done before, the consideration of relative time and succession of phenomena.—Of this  
 531 *Werner's series of formations* is a remarkable monument.  
*Mitchell*, *Whithurst* and *Saussure* have distinct claims to praise, the former for comprehensive views, the latter for diligent researches.  
 532 *Inductive Geology* was, however, principally founded on a *knowledge of organic remains*. Rude admiration of these monuments of earlier Nature animated, nearly at the same time, the Naturalists of Italy, France, and England, and the discussions respecting their origin led to the introduction of Zoology and Botany as auxiliary Sciences to Geology: and in Mr. Smith's hands to  
 533 *A correct classification of stratified rocks*, and the important discovery of the relation of *systems of organic life* to definite geological periods.  
 534 *Hypotheses* are thus devoted to oblivion, and the *modern cultivators of Geology*, aware of the grand problem committed to their industry, labour assiduously, and labour together, in the patient interpretation of Nature.

#### Materials in the Earth.

- The mean density of the Earth*, as known by astronomical and mechanical discoveries, combined with other knowledge, leads to three probable deductions as to the interior of the Planet, which are stated, and which are of great importance in limiting the range of geological speculation.  
 535 *The earthy compounds of the exterior of our Planet*, as known by observation, are referred to certain groups according to their chemical constitution.

#### Stratification.

- 536 *The regular arrangement of rocks on the surface* is shown to depend on a *regular internal arrangement* called stratification; such that the "strata are arranged, with respect to one another, in a constant order of succession." From this *superposition of strata*, with according *dehnations*, and considerable extent or continuity, it follows, that stratification is a fundamental condition of many rocks, and that the Earth is externally of a lamellar structure, the layers marking particular periods of its formation.

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#### Distinction of Stratified and Unstratified Rocks.

- 537 *From the relative situation of these two classes of rocks*,  
 538 *The distinction of their mineral characters, and mode of aggregation, and their contents*, a conclusion is drawn that they were the results of different agencies, the former deposited from water, the latter produced by heat.  
 539 *The division of geological study into two branches* is thus indicated, and the sections of the Treatise which follow are made to correspond.

#### On Stratification in general.

- 538 *Strata*: the definition of Professor Playfair limited; *interposed strata* are described; the *thickness and lamination, parallel or oblique*, are noticed; and certain *collective terms* employed, by Geologists explained.  
 539 *The series of British strata* is then presented in a tabular form, under the divisions of tertiary, secondary, and primary strata, according to the several formations and stratified groups.

#### Disturbed Stratification.

- 540 *Cuvier's fundamental principle* for investigation of disturbances of strata applied to cases of *vertical strata and contorted beds*. (See pl. i. fig. 4.)  
 541 *Faults*, or the lines of fracture of disturbed strata, considered with reference to a certain law of direction, (also applied to several mineral veins and dykes,) and to their relative antiquity: *principal epochs of convulsion* ascertained by this process of reasoning, and the leading physical features of the Earth's surface shown to be dependent on subterranean movements.  
 542 *These movements, and the disruptions of strata* which they have occasioned, are shown to be a part of the general plan of terrestrial creation, affording that variety of surface and conditions to which organic life is known to be adapted, and causing the exposure, under varied circumstances, for the use of man, of all the minerals and other useful products near the surface of the Earth. (See pl. i. fig. 5, 6, 7, 8.)

#### Internal Structure of Rocks.

- 543 *Joints in different rocks* possess peculiar characters, and communicate to them distinctive features, independent of their other structural peculiarities.  
*The general cause of joints and fissures* admitted to be contraction of the mass after partial consolidation; some general agency, like that of electricity, appealed to for the production of the symmetry and constant direction of joints in large districts; and *local changes of internal structure* referred to the application of long-continued heat. (See pl. i. fig. 9.)

#### Mineral Composition of Strata.

- 544 *Both mechanically transported sediments and chemical precipitates* are recognised among the stratified rocks, the whole series of which consists of alternate layers of several calcareous, arenaceous, argillaceous, ferruginous, and carbonaceous compounds.  
 545 *The phenomenon of alternation* must be distinguished from that of gradation of beds, though both aid to produce what is called a transition of terms in the stratified masses. (See pl. i. fig. 10, 11.)  
*The proportions of chemical and mechanical deposits* vary in the different systems, and give occasion to some general reflections as to the causes concerned.

#### Condition of Organic Remains.

- 546 *What tribes of living beings* are recognisable in the fossil state; *What portions of the original structure* are preserved; *In what condition* they were imbedded; entire, disjoined, fragmented, or worn; these questions having been answered,  
 547 *Subsequent changes of composition* may be investigated, *In plants, corals, shells, &c.*, and the effects discovered may be compared with *analogous modern processes*, and referred to the original nature of the bodies and to the peculiar influences to which they were subjected in different rocks.

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*Distribution of Organic Remains.*

- 549, 550. *The relative number of fossil and living species of plants and animals is first touched upon; the proportions analyzed with reference to the original nature of the bodies; and a comparison instituted of British recent and fossil species of zoophyta, conchifera, gasteropoda, cephalopoda.*
- 550 *The European fossil species are next tabulated.*  
*The distribution of organic remains in the Earth is next considered with reference to the number of them in different rocks; the Table given suggests remarkable inferences; the relation of kind between recent and fossil tribes being considered, and the relations of the fossils of different strata to one another, it follows, that each stratum was successively the bed of the sea, and that successive systems of strata enclose successive races of animals and plants.*
- 551 *These being of terrestrial and marine origin give us, in some degree, the history of both the land and the sea; marine races indicate the oceanic origin of limestone; terrestrial plants mark the transport of the materials of arenaceous rocks by rivers and inundations from the land; and thus, the first approximations arise toward the determination of the boundaries of the ancient oceans*
- 552 *Marine exuvix being considered, it is found that rocks of similar chemical quality have some resemblance in certain tribes of fossils; (zoophyta;) but more important is the fact, that they are associated according to the periods of their existence; so that*  
*Strata of different age contain, for the most part, different fossils.*
- Strata of the same age contain, even over large tracts, some identical and many similar fossils, according to the doctrine of Mr. Smith.*
- 553 *Repeated changes in the races of organic beings, by which they have been, at different geological epochs, successively brought nearer and nearer to the forms of existing nature, are thus established.*  
*M. Deshayes' results in this inquiry, derived from tertiary strata, are stated, and the identification of strata by characteristic organic remains is considered, and the change of organic remains put in connection with the corresponding change of mineral composition of rocks.*
- 554 *Terrestrial exuvix are shortly examined with reference to the same principles.*

## CHAPTER II.

DESCRIPTION OF THE SERIES OF AQUEOUS DEPOSITS WITH THEIR  
IMBEDDED ORGANIC REMAINS.

- 554 *The history of the successive systems of rocks, deposited from water, is preceded by a discussion of what forms their general floor or basis. It being admitted that granite and other unstratified rocks, (see p. 537.) originating from the action of heat, form this general floor. The "primary strata" are considered with reference to the hypothesis of*
- 555 *Metamorphism of rocks of all ages, and the conjecture that earlier strata than those called primary may have been absorbed into the melted nucleus of the Globe. Certain conclusions are stated; a grouping of the strata into systems follows, and these are described according to the eras of their production.*

## PRIMARY STRATA.

- 557 *The primary strata are treated of as forming the skeleton and framework of the Earth's surface, ranging along the mountain chains and groups, and encircling and dividing the great European, Asiatic, and other basins.*

*Gneiss and Mica Slate System.*

- 558 *Principal rocks described; the order of their succession examined; the origin of gneiss; its stratification; the minerals which it contains; the rocks associated with it; and the transitions from this to other rocks noticed.*
- 559 *Similar review of mica schist, quartz rock, and primary limestone.*
- 560 *The districts occupied by the gneiss and mica schist systems are next described; Cornwall, Wales, Cumberland, Scotland, (pl. i. fig. 12.) North of Ireland, South of Ireland, Brittany, Pyrenees, Central France, America.*

*Slate System.*

- 565 *Relation of this to the preceding system; (pl. i. fig. 13;) the Cambrian slate region taken as a type; dark lowest slates; red rock, middle green slates; dark fossiliferous limestone; upper slates also fossiliferous.*
- 567 *Cleavage of slate; slates of Scotland, Ireland, Isle of Man, Wales, (from Sedgwick,) Anglesea, (from Henslow,) the groups in the graywacke series of Wales, established by Murchison; slates of Charnwood forest, Cornwall, and Devon, Brittany, Pyrenees, Ardennes, Rhine Valley, Harz, Scandinavia, Tarentaise, North America.*
- 569 *"Transition" limestone shown to be analogous, in some respects, both to the primary and carboniferous limestones, but distinct from both. As a general truth, it is concluded that the whole series of strata forms but one great locally interrupted series.*
- 570 *The succession of the whole British primary series presented in a tabular form.*

*General Conclusions concerning Primary Strata*

- 570 *Are next presented under the following heads, affirmatively:*  
*General basis of igneous rocks.*  
*Influence of heat on primary strata.*  
*Organic remains absent from the lower primary strata, but frequent in the upper.*  
*Objections to the conclusion of greater manifestations of igneous agency in the older periods, considered.*

*Disturbances of the Primary Strata.*

- 571 *The effects of convulsions which happened*  
*During the accumulation of the slates, and after the deposit of the slates, considered, with reference to the mean direction of subsequent strata; exhibition of plutonic rocks, mineral veins, &c.*

*Organic Remains of the Slate System.*

- 572 *Plants, polyparia; 574, radiaria, conchifera; 578, gasteropoda; 580, annulosa, crustacea. Remarks follow each class of fossils, and a summary is given. 581, (the suggestion regarding the fossils of the South of Ireland, 577, 580, has been admitted by Mr. Weaver to be correct, M. De La Beche has no doubt that the limestones of Devonshire do belong to the transition epoch.)*

## SECONDARY STRATA.

*Carboniferous System.*

- 581 *New physical geography of the Globe at the commencement of the carboniferous period; produced by the convulsions created of, 571.*  
*Divisions of the carboniferous system:*
- 582 *Old red sandstone formation, again from local convulsive movements; its characters in the Cambrian tract, Wales, Monmouthshire, &c., Scotland, Ireland.*
- 584 *Mountain or carboniferous limestone formation; geographical extent, and modifications of the formation, illustrated by original investigations in the North of England. The several groups of the formation described, as to composition, physical geography, &c., viz., scar limestone, flagstone series, upper limestone belt, millstone grit. The mechanical origin of this latter series discussed.*
- 589 *The coal formation; its composition compared to that of the mountain limestone series.*  
*Range and extent of the coal formation; English coal fields compared in districts.*  
*The Yorkshire coal field described as a type; lower, middle, and upper series; 592, the great Northern coal fields, great South Wales coal field; 593, Forest of Dean, Somerset, &c., Flint, plain of Shrewsbury, Coalbrook Dale; 594, Clee hills, the central coal fields, Irish coal.*
- 594 *General view of circumstances under which the coal beds were deposited.*

1. Its origin from vegetables proved; (see also 547;) 2. these plants grew on land; 3. the analogy of coal beds to buried peat bogs, subterranean forests, &c., to lake and river deposits, investigated; 596, effects of the higher temperature existing in former times upon the Globe upon the growth and inhumation of plants; conclusion adopted as most generally applicable, that the plants were swept down from the land to lakes and estuaries of the sea; exemplifications of the process.



*Convulsive Movements of the Carboniferous System*

- 597 Of very general extent; 598, the Penine chain uplifted; the coal fields of Lancashire and Yorkshire divided; other elevations; the Forest of Dean, the Ardennes, &c.; relation of convulsive movements to mineral veins, &c.; observations on these.

*Organic Remains of the Carboniferous System.*

The extensive catalogues which are given are accompanied by sufficient explanations.

- 599 Plants (Polyporites Bowmanni of Lindley is a fish scale. It occurs in several other localities.)  
603 Analogy of fossil and recent plants; conclusions on this subject.  
603 Polypteria; 604, radiaria, conchifera; 606, mollusca; 608, general summary.

*Saliferous System.*

- 608 General view of the composition, subdivision, and range of this system in England; 610, remarks on certain members of the saliferous system in England; marlslates; yellow magnesian limestone; 611, laminated limestone; rock salt of Cheshire described; 612, the saliferous system of Europe; organic remains; sections in the Vosges, North-East of Germany, &c., compared with that of the North of England; remarks on salt.  
614 Circumstances attending the origin of the saliferous system; arguments for its marine origin; local absence of organic remains; prevalence of certain colours; prevalence of magnesia; difficulties with respect to the origin of the salt and gypsum.

*Organic Remains of the Saliferous System.*

- 615 Plants, polypteria; 616, radiaria, annulosa, conchifera; 617, gastropoda; 618, cephalopoda, crustacea, vertebralia, 619, summary.

*Disturbances of the Saliferous System.*

- 619 In England, only slight and few; in the Vosges, Brittany, La Vendée, Morvan, Böhmewald, Thüringerwald, Avallon, Autun.

*Oolitic System.*

- 619 Its conformity to the saliferous system in position; differences in mineral character and organic remains; the phenomenon of alternation at the base and top of the system; composition in different Counties of Europe.  
620 Classification of the English series in a tabular form.  
Range of the lias; its general characters, geographical, mineral, organic; 621, the lias formation of Yorkshire and Lancashire subdivided and described; lias of the Midland Counties; 622, of the Cotswold, of Bath and Dorsetshire, of North Britain, South Wales; lias of Autun, Chalons, Luxembourg, Württemberg, Baux; remarkable characters of lias in Switzerland.  
623 The lower oolite formation; its range, geography, elevation, escarpments, type of this formation at Bath described; inferior oolite group; 624, fuller's earth group; great oolite group; forest marble group; cornbrash. The same formation as it appears North of the Humber and in Sutherland with different characters; 626, range and character of the formation in the Midland Counties; Collyweston and Stonesfield slates.  
627 The middle oolite formation analogous to the lower oolites in mineral and geographical character; 628, less continuous. The several rocks described: Kelloway rock, Oxford clay, lower calc grit, coralline oolite, Wilts, Oxon, Yorkshire, Weymouth; upper calc grit.  
630 The upper oolite formation; Kimmeridge clay, composition, layers of ostrea delta; Portland oolite, in Portland, at Chick-grove, Brill, &c.; the dirt bed of Portland.  
631 The Wealden formation in three groups; Purbeck beds, Hastings sands, Weald clay.  
632 Evidence for the fresh-water origin of the formation.  
633 Foreign localities of the oolite system considered; range and extent of the system; its divisions really the same as in England, but generally there not recognisable; the organic remains unequally distributed.  
634 Disturbances of the oolite system; Yorkshire, Dorsetshire, Caithness. On the Continent more extensive.

*Organic Remains of the Oolitic System.*

The Tables are generally arranged so as to indicate both the relations of British and Foreign species, and the distribution of the fossils in the different formations.

- 635 Plants; 636, polypteria; 637, radiaria; 639, conchifera; 645, gastropoda.  
651 Annulosa, crustacea, insecta, reptilia, pisces, mammalia; 653, summary.

*Cretaceous System.*

- 653 Mineral character of this and other systems; remarkable surface of chalk country in England; dry valleys of the chalk hills; groups of the chalk system, as exhibited in the South of England, traced to the North, and again specified in Yorkshire; 654, Maestricht and Gosau beds; lower greensand; 655, gault; upper green sand; chalk marl; lower chalk; 656, upper chalk; its layers of flint; pyrites; fissured flints of the Isle of Wight.  
656 Cretaceous system of Ireland; the basin of Europe; France, Maestricht, North of Germany, Poland, South of Russia, &c.; 657, the Alps, Lombardy.  
657 Convulsions of the cretaceous system indicated rather by the waste of the chalk, and the accumulation of flint pebbles above, than by direct proof of disturbed rocks. *Ehrh. de Beaumont's* views; *M. Lyell's* hypothesis.

*Organic Remains of the Cretaceous System.*

- 658 Plants, polypteria; 660, radiaria; 662, conchifera; 666, mollusca.  
669 Annulosa; 670, crustacea, cirripeda, pisces, reptilia, and summary.

*TERTIARY SYSTEM.*

- 671 General view of this system of strata deposited in the sea and lakes; its geological limits toward the older deposits easily known, but toward the modern era difficult to be fixed; reasons for this in the varied nature of the deposits; the uncertainty of the applicability of a common scale of time to the independent changes of organic life on the land and in the sea; general conclusions.  
672 Physical aspect of the globe at the commencement of the tertiary epoch; various tertiary seas; tertiary system of England; lower marine formation, including plastic clay, London clay, and Bagshot sand; 674, fresh-water group of the Isle of Wight; crag, its two mineral types, vast number of shells, &c.  
675 Foreign tertiary system; under what circumstances deposited, in arms of the sea, included basins, estuaries, lakes; extent and limits of the tertiary sea of Europe, &c.; its relation to existing seas; 676, comparison of the French and English tertiaries; plastic clay; lower fresh water, upper marine, upper fresh water; Touraine beds; 678, tertiaries in the South of France, on the North of the Alps, at Vienna, in Transylvania, at Gosau, the Untersberg; 679, on the Gosau beds, molasse of Switzerland; subapennine marls; Sicilian deposits.

*Relative Antiquity of Tertiary Deposits*

- 680 This important subject is fully discussed; zoological evidence alone admitted to be of general application; mode of employing this evidence, in relation to older rocks, stated; proper mode of employing it for tertiary strata exemplified; limits of the reasoning; upper and lower terms for comparison defined; imperfections of the process when applied to particular cases without allowing for local circumstances.  
681 *M. Deshayes'* investigations analyzed; marine tertiary species compared to an upper term; (living species;) to a lower term; (basin of Paris;) *M. Deshayes'* conclusions supported by both tests.  
681 General results.  
682 Organic remains of the marine tertiary strata.

*Lacustrine Tertiaries.*

- 684 Data for reasoning concerning their antiquity; certain deposits described; in Central France, in Provence, at Emmen.  
685 Ligantic deposits of Switzerland, &c., of Bovey Tracey, the Meissner.  
686 Organic remains of the lacustrine tertiaries.  
688 Dislocations of the tertiary strata in the South of England.



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## DILUVIAL DEPOSITS.

- 688 *Distinctions between these and the tertiary strata*; origin of the term diluvial; relation of the phenomena it includes to the *Noachian Deluge*; proofs of the extraordinary violence of water afforded by these deposits; example of the transport of detritus from the Cumbrian mountains to the South-East, from the Lickoy-hill to the East, from the Lincolnshire wolds.
- 690 Still more extensive effects of analogous causes among and in the vicinity of the Alps; *circumstances* attending the dispersal of the *erratic blocks* of the Alps, and others from Scandinavia, as to arrangement, number, magnitude; direction of the currents to which they owe their transport; general inference on this part of the subject.
- 691 *Gravel deposits*; *animal population* at the time of these diluvial currents widely diffused over the Northern regions of the globe; consisted of many species of quadrupeds congenious with those now living, but for the most part specifically distinct.
- 692 That they really *lived in those regions* where their remains occur proved by several facts, especially by the history of the ossiferous caves.
- Ossiferous caves*; their situation, characters, how formed, how filled with bones; Kirkdale cave tenanted by hyenas; 694, Kuhloch tenanted by bears, which died there; Mendip ochre caves and Oreston caves filled by accident and aqueous currents.
- 695 *Ossuous breccia* of the Mediterranean analogous to these latter caves, and filled like them.
- The question of the *climate of the Northern regions* in the diluvial or elephantal era investigated as a question of Philosophical Zoology; 696, new evidence brought to bear on the subject; the hair-covered fossil animals of the Ice Sea, and the association of *recent shells with extinct animals* in Yorkshire. *Other problems* considered; geographical extent of the phenomena; 697, length of the diluvial period; geological monuments of the existence of man; 698, supposed *contemporaneity of human and quadrupedal bones* near Leipzig, Nice, the South of France; the latter example investigated, and a general conclusion adopted on this subject; an attempt to assign the causes of the diluvial phenomena.
- 699 *Table of Organic Remains in Caverns and Superficial Deposits subsequent to the Tertiary Period.*

## DEPOSITS OF THE MODERN ERA—MODERN CAUSES IN ACTION.

- 701 The relation of terraqueous agencies in ancient and modern eras is a proper subject of geological inquiry. On this point the differences of opinion are great, but reducible to three classes, one denying the analogy of ancient and modern physical operations; another admitting agreement in the mode of operation; a third asserting identity of kind and equality of effect; modern causes in action are then examined.
- The wasting effects of the atmosphere*, chemical, mechanical, or combined, on felspathic and other rocks, contrasted with the conservative power of the ground; waste from humidity, exemplified from changes of heat and moisture, parallel to artificial surfaces of several kinds of stones; 703, influence of frost on slaty rocks; in the Righi mountains.
- Effects of rain* on druidical monuments, on grit rocks, in limestone cliffs and floors, producing channels like miniature valleys.
- 704 *Effects of inundations*, in Scotland, in Yorkshire, in the Alps.
- Effects of Streams and Rivers.*
- 705 Of two kinds, excavating and transporting; *erosive effects* exemplified in Tynedale, in the Lincolnshire rivers, in various river deltas, in Etna, in Auvergne.
- Waterfalls and cataracts, how formed, and continued; at what rate they waste the rocks, and cause recession of the fall; Falls of Niagara.
- Transporting action* of streams discussed; *rivers without lakes*; waste of the uplands causes elevation and fills irregularities of the lowlands; the Yorkshire (Ouse); the valleys near Schaffhausen; in low ground, and at the mouths of rivers, large accretions of sediment happen, new land is formed, and the river mouth is carried forwards or turned in new directions; 706, *the materials* transported vary much, and remind us of the ancient earthy and carbonaceous strata, to which a similar origin has been ascribed; the arrangement of these materials and the general effects of rivers referred to the

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- initial wasting effects of the atmosphere, the power of the river current, and the character of the valley itself.
- 707 *Rivers with lakes* occasion other peculiarities; the lake receives all the sediment and discharges the water pure; new land is thus formed at the head of the lake; the materials in it being arranged in particular inclined conical surfaces, and measuring the whole transporting effect of the river since it began to flow.
- Lacustrine deposits* of shelly marl, clay, peat, &c., are analogous to the ancient fresh-water tertiary beds.
- 708 *Deltas* formed in the sea at the mouths of rivers nearly as in lakes, and coasts extended as on the Adriatic by the same processes; the nature of the materials of which they consist varies according to locality, and both in this respect and in geographical area deltas present close and frequent analogies to some old sedimentary rocks.
- Rivers at the mouths of rivers*, how formed; area of remarkable deltas; geological chronometer formed by them, why defective.

## Action of the Sea

- 709 Erosive and transporting, as in rivers; *wasting of cliffs*, how occasioned; to what degree on the coasts of Yorkshire and Norfolk; extension of marsh land on the same coasts, how produced; different effects of the sea; alternate production and destruction of land, incessant action of the sea in arranging and disturbing the sediment gathered from the land.
- 709 *Coast islands*; their growth, quantity of carbonate of lime solidified by them; comparison of coral reefs with certain old limestone strata, how far just, and in what respects delusive.

## CHAPTER III.

## DESCRIPTION OF THE ROCKS PRODUCED BY IGNEOUS AGENCY.

- 711 *Introduction*, containing a general view of the subjects to be discussed.

## PART I.

- On Rocks produced by Igneous Operations of a similar Nature to those now taking place.*

## SECTION I.

- Description of Volcanic Phenomena in different Parts of the World. General Notion of Volcanic Action.*

- 712 *Phenomena attributed to volcanic action*; phenomena admitted to be volcanic; evidence of volcanic action: local internal commotion; the structure and appearances of the mineral masses on a large scale; the characters of individual rocks; 713, these characters specified; trachyte, grey-stone; analogy of other volcanic rocks to these.
- Division of volcanic products* according to their age; the age of valleys assumed as definite, and the volcanic rocks divided by this standard into antediluvial and postdiluvial.
- Postdiluvial volcanic rocks*, mineral characters of these.
- 714 *Antediluvial volcanic rocks*, their characters; distinction of subaerial and subaqueous modern volcanoes.

## Active Volcanos of Europe.

- Vesuvius*, historical view of its condition; destruction of Pompeii and Stabiae by dry ashes; of Herculaneum by tuffaceous mud; other eruptions noticed.
- Phlegrean Fields*, subsidence, of their volcanic excitation since Vesuvius became active; the phenomena still manifested in the
- 716 *Solfatara* described; sulphureous vapours; decomposition of the trachytic rocks.
- Monte Nuovo*, thrown up in the XVIIIth Century; after earthquakes and flames, consists of loose materials ejected in a few days; heat still manifested at its base.
- Grotto del Cane*, near Lago Agnano, its mephitic vapours.
- Puzzolana*, extent of this deposit along the base of the Apennines; its composition, antiquity, elevation above the sea.
- Temple of Serapis* at Puzzuoli, circumstances which indicate repeated changes of level affecting this locality.
- Islands of Phocæa and Ichia*—of varying tuffaceous composition; later pumiceous products of Ichia; present high temperature about it.

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718 *Other parts of Italy*—Mount Vultur; great antiquity of its action.

Rocca Monfina; buried town at Sessa; Ponza Islands; volcanic phenomena of the *Papal States*, Albano, Rome, Viterbo

*North of Italy*—Valterra; Egeanean Hills.

719 *South of Italy*—Lipari Islands, hot springs, volcano; Stromboli, its unintermitting eruptions; beds of puzzolana; dykes.

*Sicily*—alternate volcanic and neptunian deposits of the tertiary era; Val di Noto; Maccaluba; Etna, its vast mass comparatively modern; consists of lava, beds, and tuff, with dykes of trachyte and basalt; erupted in the air, while those of the Val di Noto took place under water.

*Sciaccia*—of recent date, and transient existence; elevated on a line of volcanic action; from deep water.

720 *Grecian Archipelago*—ancient and modern elevations affecting Santorino and the adjacent islands; line of volcanic operations through Milo and Argentiore to the ancient Methone.

*Iceland*—great scale of its continual volcanic excitement; lines of volcanos; vast lava flood of 1783; island which rose and sunk again in that year; Geysers, their intermitting character explained; solution of silica.

*Jan Mayen*, supposed to have been in action within a short period.

#### *Extinct Volcanos of Europe.*

721 *Portugal*, on the Eastern side of, near Lisbon, in Beira.

*Spain*—volcanic appearances of Cap di Gaeta; volcanic cones of high antiquity near Olot.

*France*—North-East of the Pyrenees, Cevennes, Vivarais, Puy, Cantal, Mont Dur; volcanic masses of Auvergne, the Vivarais, Puy en Velay, produced since the date of the valleys, though some are cut by existing streams into ravines, seventy craters in Auvergne; five domitic hills near Clermont distinct in their origin from the other volcanic masses; supposed by Von Buch to have been heaved up, not ejected, characteristic phenomena bearing on this question specified.

722 *Germany*—Eifel volcanos, cones, craters with lakes; few traces of lava streams; referred to comparatively modern period.

Siebergengeburge: basaltic and trachytic hills protruding through schists superposed on tertiary brown coal; basalt of the Westerwald, Vogelsgeburge, Frankfort, Hanau, Cassel, Eisenach, alteration of stratified rocks.

Odenwald, Kaiserstuhl, North of Lake Constance, Rhodengeburge, Fichtelgebirge, Toplitz, Riesengeburge, Erzgebirge; overlying masses of basalt on the western borders of Moravia.

724 *Hungary*—five volcanic groups in the North of Hungary; 1. Schemnitz and Krennitz; 2. near Graa; 3. mountain of Matra; 4. from Tokai to Eperies; 5. Vihorlet, connected with trachytic mountains of Marmarosch; all of high antiquity in the tertiary period, erupted in a country full of lakes.

*Syria*—the Gieschenberg trachytic group on the Euphrates.

#### *Volcanos of Asia.*

*Asia Minor*—the Troad; Smyrna.

*Dead Sea*—hypothesis proposed concerning the course of the Jordan, and formation of this sea.

*Red Sea*—active volcano of Zibbel Ten.

725 *Central Asia*—Mount Ararat, Demavend; reports of volcanos in the great depression of the Earth's surface, including the Caspian, &c. Aral Toobe, Pechan, Tourfan.

*Kantokutka*—very active volcanos; volcanic line of the Aleutian Isles to Alaschka; rising of the trachytic island of Unalashchka in 1795; line of volcanic vents by the Kurilean Islands, the Isles of Japan, Loo-Choo, Formosa, the Philippines, Sanguir, Celebes, Ternate, Fidore, the Moluccas, Sambawa, Java, Sumatra, and Barren Island; Eastward range of volcanic phenomena from Sambawa.

*Pacific Ocean*, volcanic groups and islands of.

#### *Volcanos of Africa.*

726 *Madagascar*—Mauritius, Bourbon, its frequent lava streams and ejections; St. Helena, Ascension, Tristan d'Acunha, &c.; Cape Verd Islands.

*Canary Islands*—Teneriffa, variety of its volcanic products,

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the Peak; crater eruptions; flank eruptions; other islands the Caldera of Palma; origin of the Barancos; Lancerote.

*Madeira*—Mount Atlas.

*The Azores*—St. Michael, El Pico; Island of Sabrina raised and sunk again, 1811.

#### *Volcanos of America.*

727 *The Antilles*—nature of these Islands; the volcanic portion classed in two divisions: 1. Grenada, St. Vincent, St. Lucia, Dominica, Montserrat, Nevis, St. Christopher, St. Eustachia; 2. Martinique, Guadeloupe, Antigua, St. Barthelemy, St. Martin, St. Thomas; connection of the Caraccas mountains, through the Antilles, with the mountains of Porto Rico, St. Domingo, Jamaica, Cuba.

728 *Continent of America*—*North America*—California; Mexico; great theatre of volcanic action; variety of rocks here produced; East and West line of volcanos extending to the Rivillagigedo Isles; Jorullo, its recent origin, described according to Humboldt; other lines and groups of volcanos in Guatimala, Nicaragua, Columbia; connection of these latter in one system; relation of this line of volcanos to the Andes.

*South America*—Extension of the line to Chili where sixteen active volcanos exist; thus all the Western coast of America, South of California, one great theatre of volcanic action.

#### SECTION 2.

##### *Other Phenomena referable to Volcanic Action.*

729 *Review of the preceding observations on volcanos; other phenomena to be considered.*

*Earthquakes* proved to be connected with volcanic agency, by coincidence or reciprocation of period; instanced by the relation of the eruptions of Etna and Vesuvius to certain earthquakes; other evidence from Columbia, Quito, Chili, Lancerote, Teneriffe.

730 *Phenomena of earthquakes; shocks, undulations, vibrations; subterranean noises; eruption of flames; alteration of levels of water; meteorological phenomena; speculations as to other than volcanic causes of earthquakes; electrical accumulation; internal cavities; great extent of the shock of earthquakes no argument against their volcanic origin; not irreconcilable with moderate depth of the exciting cause.*

731 *Thermal waters* also connected with volcanic action, because they emit the same gases as volcanos, sulphuretted hydrogen, carbonic acid, nitrogen; this latter given off by Vesuvius, Seneca; also by hot springs of Castellamare, near Vesuvius, and Auvergne; also by thermal waters of the Alps, Bath, Buxton, Bakewell, Stoney Middleton, and Taaf's Well; also in Ceylon and Venezuela; quantity of this gas evolved at Bath.

732 *Situation of thermal waters* shows their relation to volcanic agency; near volcanic groups, elevated chains of mountains, along lines of dislocation, &c.; instances in England.

*Heat of such springs* related to the period of volcanic excitement, hottest when that is still active, least warm when that has been long extinct; no local chemical action adequate to account for such effects.

733 *Carbonic acid in springs* also indicative of volcanic action; proofs drawn from the position of such springs, in relation to thermal waters, and dislocated strata.

*Mud volcanos or saltes* not really of volcanic origin, but due to local chemical changes, as in Sicily, near Modena, New Arslalusia, Trinidad, and Island of Taman; often excited among the substances produced by ancient volcanos: salt springs of Ohio.

*Emanations of inflammable gas* not admitted as evidence of volcanic action in coal mines, on the Apennines, near Grenoble, in Albania, Baku, where considerable eruptions arise from this cause.

#### SECTION 3.

##### *Theories of Volcanic Operations considered.*

734 *On what data* such theories to be constructed, in one class of theories heat considered as an effect, in another assumed as the general cause; the former limited by rejection of unsatisfactory hypotheses to a certain chemical postulate, viz. the oxygenization of metallic bases of the alkalis and earths; the latter reduced to the general theory of internal heat of the Globe; mode of investigation to be followed for the discovery of truth.

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735 *Geographical distribution of volcanos*; linear and central volcanic systems, supposed difference of their origin; great volcanic bands.
- 736 *Proximity of active volcanos to the sea or water*, a general fact to which hardly any real exceptions occur; extinct volcanos appear to have had the same relation.
- Products of volcanic operations*; aeriform fluids evolved, steam, chlorine, sulphuretted hydrogen, sulphurous acid, carbonic acid, nitrogen; circumstances accompanying their appearance.
- 737 *Substances not gaseous* sublimed; petroleum, sulphuric acid, boracic acid, muriate of ammonia, specular iron ore, muriate of soda, sulphur.
- Solids, liquid substances* ejected; lavas, their chemical composition; temperature of flowing; fusibility of basalt; analysis of the lava of Etna; notions concerning the fluidity of lava.
- 738 *Loose fragments* ejected analogous to lava; general relation of solid volcanic products to trachyte; that rock considered with regard to its origin, from the fusion of granitic rocks; its geological relations strengthen such an opinion.
- 740 *Constitution of a volcanic mountain* in general; crater of an active volcano; explosion; causes scoria; conditions which determine the frequency and force of eruptions.
- Craters of eruption*; their effects described; quaquaversal dip of the volcanic accumulations round such craters.
- 741 *Craters of elevation*; that such exist probable from their own appearance, as in Great Canary, in Palma; from the existence of domes of trachyte, as in Auvergne; that such were uplifted, pools offered, the structure of Puy Chopine examined; other cases of crater formed elevations of rocks not volcanic in the Eifel, &c.; alteration of common limestones to dolomites; supposed sublimation and transfer of magnesia; Crick Hill a case of elevation.
- 743 The same subject illustrated by testimony of the elevation of volcanic rocks; instances recorded, near Santorino, near Unaslachka, Sciacca, Jomulo; cavities in volcanic mountains; falling in of Papendayang.
- 744 *Craters of elevation*, how distinguished from those of eruption; to what extent it is supported by distinct evidence; how far admissible; review of this part of the subject.

## SECTION 4.

*Theory of Volcanic Operations.*

- 745 Recurring to the two theories formerly mentioned, their prominent characters are contrasted; the extent to which the theory of internal heat appears to satisfy the conditions of the case specified; the imperfections of this theory stated; products of volcanos examined to test the probability of the theory of oxidation of metallic bases; bearing of the known mean density of the Earth on this discussion.
- 746 *Statement of the theory of chemical action*; existence of alkaline and earthy metalloids at moderate depths in the Earth; effect of admitting oxygenous substances to them, under the land, under the sea; effect of admitting water to such metallic bodies traced through the various chemical products of volcanos; general conclusion of preference for the chemical theory of volcanos on the ground of its more fully embracing the numerous phenomena observed.

## PART II.

*Description of Rocks attributed to Volcanic Action taking place under Circumstances different from those before considered.*

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*On Trap Rocks.*

- 749 *Introduction*. Connection of the study of modern volcanos with inquiries concerning the effects of the same agencies in ancient geological periods. Composition of basalt; 750, greenstone, syenite, claystone porphyry, pitchstone, &c., &c.; general characters of the foregoing rocks; their mode of occurrence; interposed beds; 751, prismatic structure; spheroidal structure; tabular trap; dykes of trap; their effects on contiguous rocks, on coal.
- 752 *Origin of trap rocks* derived from igneous agency; some of them quite analogous to the products of existing volcanos; Wernerian hypothesis of the aqueous origin of trap; 753, arguments advanced in its favour shown to be fallacious.

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- 753 *Differences between lava and basalt* explained; accounted for by Dr. Hutton on the principle of pressure modifying the effects of heat; experimentally proved by Sir J. Hall; why submarine lavas cool slowly.
- 755 *Prismatic structure* accounted for; found in recent lava, at Torre del Greco, at Niedermendig, in the Vivarais; greater frequency of dykes in trap rocks than in modern volcanic rocks; such dykes occur in modern volcanos, as in Somma and Vesuvius; reasons why they should more abound in submarine lavas.
- 756 *Trap rocks, at what periods* formed; cases of the formation of trap among old secondary strata at intervals during their deposition, and at subsequent periods; much of the trap of Ireland and Scotland posterior to the age of the chalk; remarkable prevalence of trap rocks during the tertiary period; abundance of trachyte formed in the same period.

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*Granitic Rocks.*

- 757 *Various conditions of the production of igneous rocks*; distinction of submarine, subterranean, and subaerial volcanic products; granitic and basaltic rocks compared, and thus a general scale of igneous products indicated.
- Rocks allied to granite; general argument for the igneous origin of granite; peculiar character of granite; from what circumstances derived.
- 758 Comparison of ancient and modern pyrogenous rocks; felspathic, hornblende-felspathic, hornblende; structure of each group; granite veins; view of the mineral composition of granite; remarks on its constituent minerals, felspar, quartz, mica, the order of their crystallization; contemporaneous veins in granite; unbedded minerals in granite; considerations on the crystallization of granite; its elementary composition; chemical analogies among pyrogenous rocks.

## SECTION 3.

*Relative Age and characteristic Phenomena of Pyrogenous Rocks.*

- 760 *Age of plutonic rocks*, how to be obtained; by reference to the date of convulsions, formation of veins, intermination with rocks of known age, division of strata by dykes.
- Arran, an example of pyrogenous rocks* in general; its general features; its granite upheaved in a melted state, at a certain period, traversed by dykes of other igneous rocks; the general features of these dykes described; 761, alterations of stratified rocks; geographical relations of the pyrogenous rocks; no granite dyke; no hornblende granite; dependence of dykes and veins on granite elevations.
- 761 *Granite described*; its ages in Britain various; granite veins abundant; granite without veins rare in Britain; veins in slate of Aran, in limestone, &c. of Glen Tilt, in kyllas of Cornwall.
- 762 *Felspar porphyry* described in Ben Nevis, Ben Cruachan, the Cumbrian mountains, North Wales, Cornwall.
- 763 *Syenite* of Malvern; remarkable position of strata in contact; syenitic dyke.
- Hyp. rathene rock* of Cuchollin, Carrock, Radnorshire, Cornwall; that of the Valteline described in its relation to granite; that of Skye in connection with syenite, greenstone, lias &c.
- 764 *Gabbro, diatrag rock*, serpentine, &c.; localities of these rocks, stratification of serpentine considered.
- Greenstone* of Salisbury Craig described; its effects on the sandstones and shales included and otherwise placed in contact; subsequent elevation of the rocks.
- 765 *Basalt of the North-East of Ireland* described; section of Fairhead; contact with lias at Portrush; dykes in red conglomerate, in coal measures, in chalk; change of this latter to granular limestone.
- 766 *Basaltic formation of Upper Trentdale* described; its relation to the carboniferous limestones, shales, and sandstones; remarkable dykes apparently related to the great "Whin Sill;" metallic ores by the side of a dyke.
- Melaphyre*; opinions of Von Buch concerning it; elevation of the Alps; dolomitization of limestone; how this latter supposed to be accomplished; probable fate of this hypothesis.
- 767 *Claystone* of Córighills and Tormore in Arran.
- Claystone porphyry* of the West coast of Arran.

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*Amygdaloidal trap* of Kinnoul; its mineral composition; effects on sandstones and shales of Oban.

*Wacke* of the Caltun Hill alternates with bituminous shale and argillaceous ironstone.

- 768 *Pulchstone* in Arran; dykes and interposed beds; mixture with hornstone and greonstone in dykes at Tormore; that of Corygills described.

*Trap tuff*. Porphyritic breccia, "volcanic sandstone," as seen in Cumbria, in Glen Coe, &c., near Edinburgh, near Oban, and in the Caradoc and the Wrekin.

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##### Mineral Veins.

- 769 *State of knowledge* on this subject; want of union between men of science and practical miners; distinction of rocks, dykes, and mineral veins; plan of investigation in the following Treatise.

*Substances in a mineral vein*; extremely various: in various states of chemical combination; metals, pure, alloyed, mineralized by union with combustibles, with oxygen, with acids; non-metallic substances, the gangue or vein stuff, crystallized, massive, earthy; the "Rider."

- 770 *Modes of aggregation of the substances*; veins filled with one or many sorts of mineral matter; distribution of the different substances various.

General idea of a mineral vein; laminae of successive crystallization; successive deposition of these laminae a very plausible hypothesis; less satisfactory on a great scale; the subject further examined; *Werner's opinion* as to the association of certain minerals in veins; occurrence of rolled and fragmented masses in veins; *general form of veins*; lake veins, pipe veins, flat veins, gash veins, strings and feeders of a vein; *ridered rock*; *metallic substances disseminated* in rocks near veins, in Cornwall, the North of England; tin disseminated in granite; tin floors of Cornwall; stock-works of the Parys mine, Dan-nemora Geyer.

- 771 *Relations of veins to each other*; phenomena at their intersection, as to richness, reciprocity; age of veins as indicated by their intersections; this subject examined; *fundamental postulate*; objections to the admission of this; evidence of Cornish mines on this subject considered; effects in the neighbourhood of a vein; character of veins in different rocks; phenomena of contemporaneous veins; this term limited in its application; conclusion of the argument; intersection of veins resumed; appearances at the crossing; slips and dislocations accompanying veins; real and apparent movement of the mineral masses.

- 772 *Geographical relations of veins*; situations and character of veins, as to height of ground, depth from surface, variation of contents in proportion to depth; *dimensions of mineral veins*, length, width, &c.; *directions of mineral veins*, a general law hereon; East and West direction common in Britain and Europe; directions of veins related to their antiquity in Cornwall, in Germany; *direction of mining districts*.

- 773 Connection of veins, fissures, main joints, and cleavage, &c. shown to be real; *relation of mineral veins to the rocks* which inclose them; importance and difficulty of this subject.

1. Relation to the different kinds of rocks; are veins independent of their chemical and mineral diversity? are certain metals specially associated with particular rocks? instances for and against this notion, in Cornwall, in Silesia, &c. in the North of England; various circumstances of the latter case; quantity of lead in the different "bearing beds" of Alston Moor; general conclusion.

*Walls of a vein*, altered as if in contact with trap, smoothed and polished; Sticksade, evidence it affords of movement of the masses.

- 776 2. *Relation to different ages of rocks*; evident as a general fact, metallic veins most abundant in primary and old secondary strata; the same relation obtains in rock dykes; very modern veins at Joachimsthal; contents of veins supposed by Werner to characterise their ages; his descriptions of eight systems of veins.

- 777 3. *Relation to local centres of igneous action* inquired into: in the older rocks veins most abundant where igneous action has been much developed, and *vice versa*; in newer rocks the same relation decidedly proved; conclusions adopted on this subject; under what limitations; successive production of trap rocks and mineral veins under the same physical region.

- 778 *Electricity of veins*; Mr. Fox's experiments considered.

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## CHAPTER IV.

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#### SECTION 1.

*On the Consolidation and Alteration of Stratified Rocks.*

- 778 *Effects of plutonic on stratified rocks*; consolidation, partial fusion, vitrification, crystalline re-arrangement, generation of new minerals; sublimation of particular substances, coal, sulphur, bitumen, &c.; *relation of igneous rocks to convulsive disturbances of the strata*, such that their local exhibition depends on the same cause; comparison of these two orders of effects; existence (simultaneous or successive) of *raised rocks* below the strata admitted, and their elevations ascribed to mechanical agency.

*Consolidation of the strata* shown to be in the ratio of their age, or rather of their proximity to the inferior heated regions of the Globe; the lower strata not merely consolidated, but partially altered in structure, composition, arrangement of particles, &c.; gneiss, mica slate, clay slate, considered in this respect; similar review of the secondary and tertiary systems of strata, showing the decreasing effects of heat in them.

Effects of heat on the deposition of certain primary strata.

#### SECTION 2.

##### On Disturbances of the Strata.

- 780 1. *Geological periods of convulsion*; proofs of convulsion, founded upon an investigation of the sedimentary deposits, in agitated water, in tranquil water, with or without rivers; sloping deposits rare and peculiar; horizontal deposits of general occurrence; convulsions, how proved directly; how to be inferred from collateral effects; how to determine the *epochs of convulsion*, on the scale of successive deposits; limits of greatest and least antiquity, how to be assigned; question as to the *duration of the convulsions*; were they effected by one or a few vast efforts, or by many small and graduated movements; faults examined with this view; *relation of such faults to areas of convulsion*; inference in favour of short periods of great violence.

- 783 Table of the geological periods of convulsions in Great Britain; another Table applicable to Europe.

2. *Direction of convulsive movements*, governed by certain laws; *Phe de Beaumont's hypothesis* stated; in what manner it can be fairly tested; difficulties in the process; dislocations which are not known to be of different ages, and others which are known to be of different ages, employed as data for examining the hypothesis; two of M. de Beaumont's systems of convulsion analyzed; more limited inquiry recommended and exemplified.

- 786 *Direction or strike of the strata* generally parallel to the great chains of mountains, both in the Old and New World, North-East and South-West strike of strata very frequent; parallelism of strikes of strata and curves of magnetic intensity according to M. Necker, in Europe, North America, and Asia.

- 787 3. Effects of convulsions in altering the *relations of land and water*; elevation of land, at what periods, by what processes effected; general impression on this subject correct, but not complete; *partial elevation of land* a consequence of convulsions, proved by examination of mountain chains and groups, which show angularly elevated strata, and indicate vertical movements; elevation of land above the sea, on what evidence to be admitted.

*Ocean level*; speculations on this subject; phenomena of this level, within certain limits, examined; by what causes variable; 1. temperature of the water; 2. general change of the dimensions of the Globe, of its internal nucleus; 3. internal movements capable of slightly changing the mean level of the ocean; calculation of the amount upon several assumptions; conclusion adopted, that the mean oceanic level is nearly permanent.

Elevation of land not in all cases convulsive, but in some cases gradual; extent to which this principle may be applied; proposal of a hypothesis on this subject, that the concentric interior masses of the spheroid may not be of uniform density, and that the densities on any one radius may be variable by reason of intestine movements; probable effects of such convulsions.

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- 789 Sketch of the relations of land and water, prior to the formation of strata, during the formation of primary strata; at the commencement of the carboniferous epoch; origin of coal; places of growth of the coal plants, before the saliferous epoch; before the oolitic epoch; difficult problem of the relative elevation above the sea of the successive secondary systems of strata.
- 791 4. Effect of convulsions on the deposition of strata and organic life; *mineral characters* of the several systems of strata compared with the sedimentary deposits now formed by the ordinary processes of Nature; origin of diversity of sediments; no universal strata, *not even* the oldest primary strata, still less the newer rocks; contemporaneity of changes of mineral character and general or local convulsions; dependence of the former on the latter; sudden or gradual effects of this nature; case suited to modern hydrography proposed.
- 792 Successive *races of marine animals* might be changed by the same operations; transference of organic life; co-ordination of convulsions, changes of organic life and mineral sediments; *fresh-water and marine alternations* dependent on local subterranean movements; difference of cases; proximate and remote convulsions; corresponding effects.
- 793 *The Weald of Sussex*; Mr. Lyell's hypothesis on its gradual rise and the gradual transfer of its wasted materials to the tertiary basins of London and Hampshire examined; circumstances favourable to it: elevation of the Weald; waste of the deposits there; analogy of the sediments of the two tertiary basins named; resemblance of these to the strata of the Weald; *principal objections to it*; want of correspondence of the succession of beds; deficiency of any rolled masses derived from the Weald.

*General View of the State and Progress of Geology.*

- 793 Distinction of Geology from Cosmogony; influence of the Geological Society of London; state of preparation for a geological theory; examination of some leading problems.
- Lapse of time*; scale of geological chronology, how to be formed; rate of natural processes; augmentation of low lands; shifting of sands; erosion of river channels; difficulties in the reasoning even for comparatively recent terrestrial phenomena; mode of proceeding in the case of older marine periods exemplified. The evidence being,
1. The mechanical deposition of sands, clays, conglomerates, &c.; proof of their formation occupying time; possibility of estimating the proportionate times; assumed unit of time; calculated period of the coal deposits; conglomerates prove that long time elapsed between the deposition of strata locally in contact.
  2. Chemical deposits of limestone; difficult to reduce to periods; method proposed of referring them to *equival* mechanical deposits.
  3. Alternation of chemical and sedimentary deposits.
  4. Imbedded organic remains; shells of all ages in one only bed; proof of lapse of time; number of shells in a bed not

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- admitted as proof; position of certain plants in sandstones opposed to very great rapidity of deposition.
5. Successions of *races of organic beings* in the same basin; impressive nature of this evidence; proof of long, but at the same time unknown, periods; inutility of attempting to determine these at present.
  6. Successions of convulsions in the same physical region.
  7. Alternation of marine and fresh-water products.
  8. Alternation of aqueous and igneous products.
  9. Metamorphism of rocks.

*Successive Conditions of the Globe.*

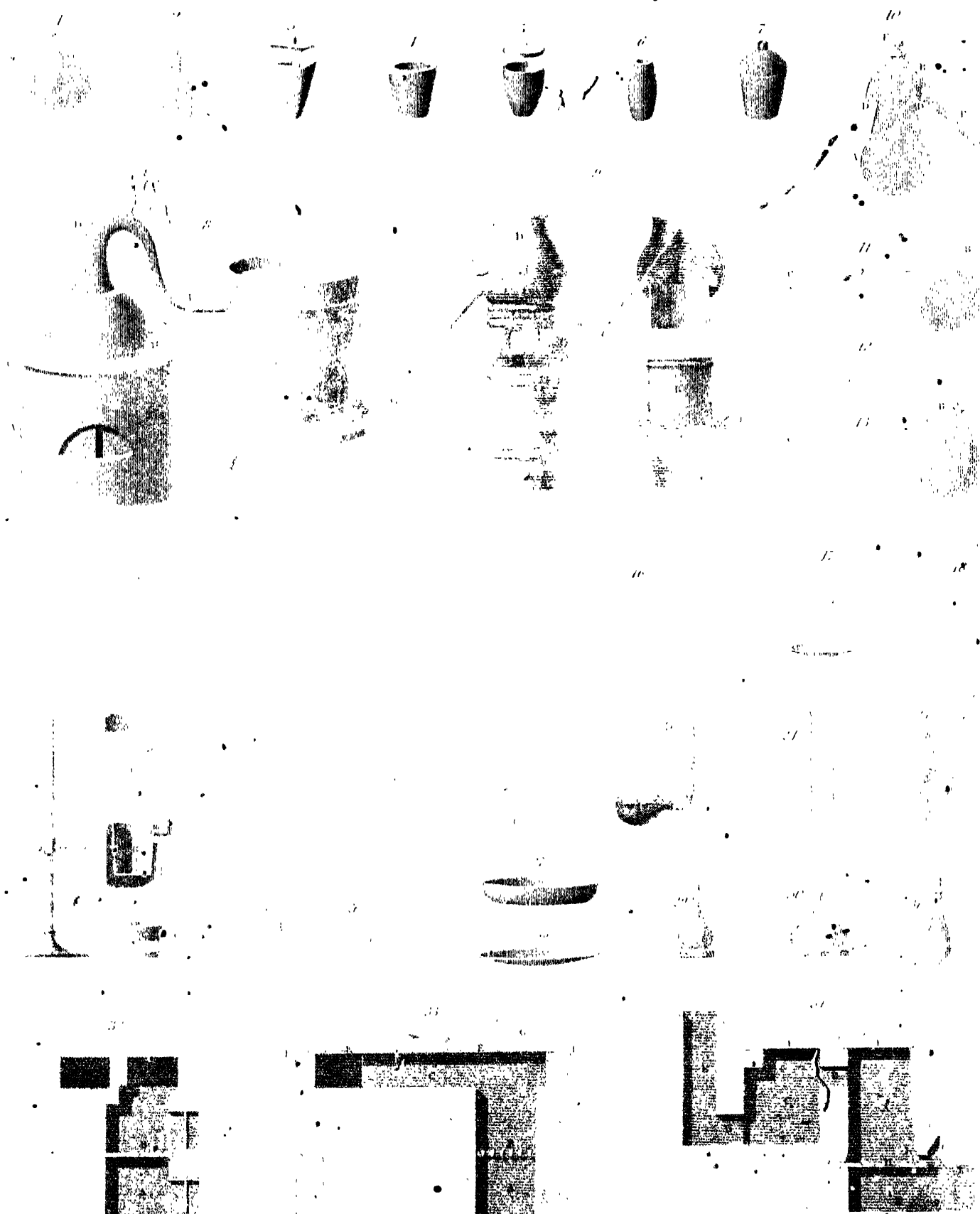
- 797 Limitation of the inquiry; laws of existing Nature must guide our inquiries; what is possible to be known; sensible *constancy of the dimensions* of the Globe in historical periods; what it proves and allows concerning internal heat and secular refrigeration.
- Volcanic action need not be referred exclusively to either of the theories formerly explained.
- Displacement of the Earth's axis*; why not to be admitted as a geological cause.
- Origin of terrestrial organic life*; the general analogy of old and modern systems of material beings; special analogies of extinct organic forms to those of particular modern regions.
- Alternate periods of convulsion and repose* shown to have occurred locally, with definable circumstances of land and sea; application of this principle to large portions of the Globe, by Leibnitz and others; contrary view of Mr. Lyell, uniformity of natural agencies, and continual equality of the sum of their effects in a given time; these opposing views reduced to their postulates, *varying condition and unlimited duration*; which of these is true must be found as a result of investigation, not assumed as a basis of argument.

*Successive Condition of the Materials of the Globe.*

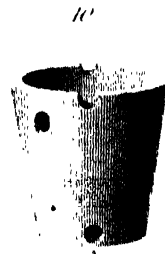
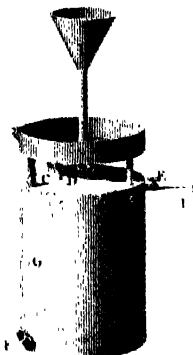
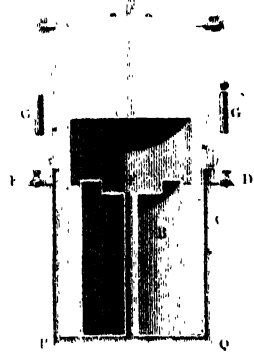
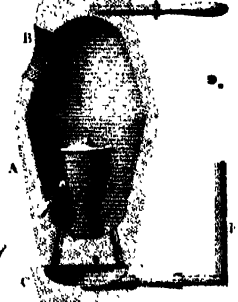
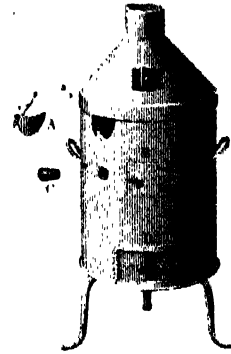
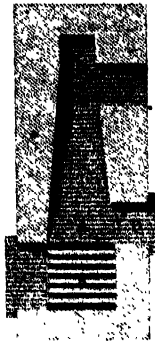
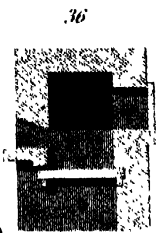
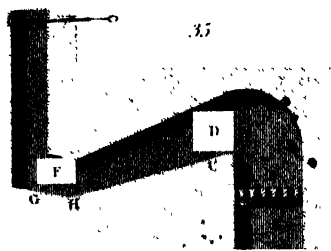
- 798 *Origin of the elementary substances* no part of Geology, but then changes of condition a proper subject of research; *Hernesian hypothesis* of a chaotic ocean; *Leibnitz's view* of the effects of a globe progressively cooling; *Hutton's hypothesis* of continually renewed phenomena.
- Certain sedimentary substances traced through several conditions; tidal sediments, diluvial accumulations, millstone grit; derivation of sedimentary from pyrogenous rocks through one or more steps generally allowed.
- Origin of limestone; in modern times from chemical action, from mechanical erosion, from transported oxides, from vital phenomena; stratified limestones considered with reference to Dr. Hutton's hypothesis of decaying and renewed continents, and the ultimate reference of all earthy substances to rocks of fusion; Mr. Lyell's view that this derivation of sedimentary from pyrogenous rocks at the surface of the Earth is balanced by reconversion of the former into the latter towards the interior, shown to be not fully in accordance with the hypothesis of uniformity and continual compensation of the effects of internal and external terrestrial agencies.

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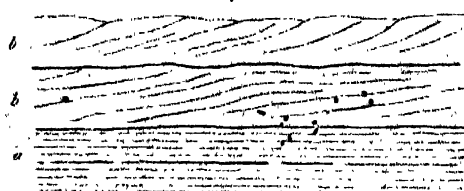


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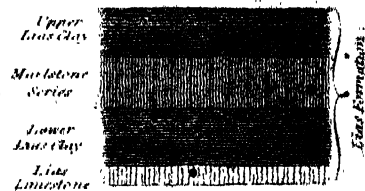
*Lenticular interposed and divided beds*



### Parallel and oblique illumination



### Batholith Formation

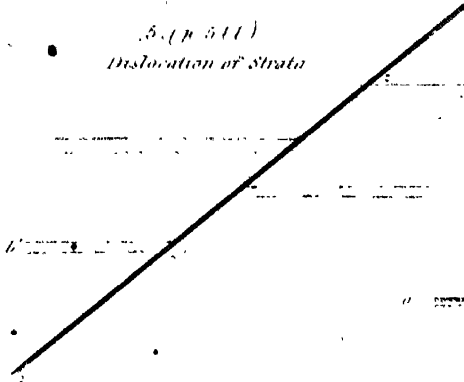


### *New Red Sandstone Formation*

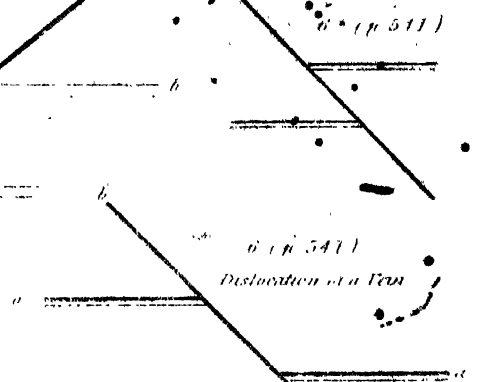
*converted Strata*



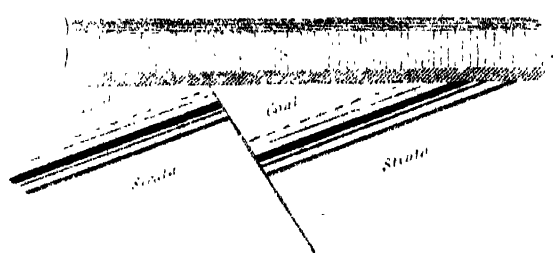
### *Dislocation of Stratos*



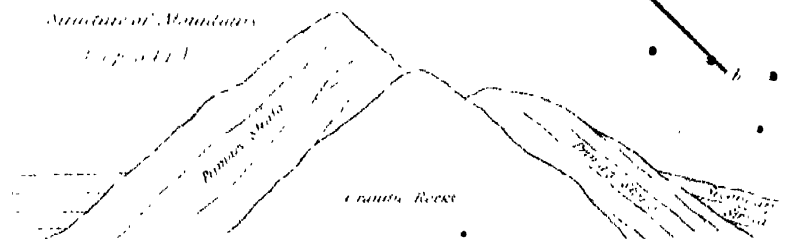
Dislocation of a Few



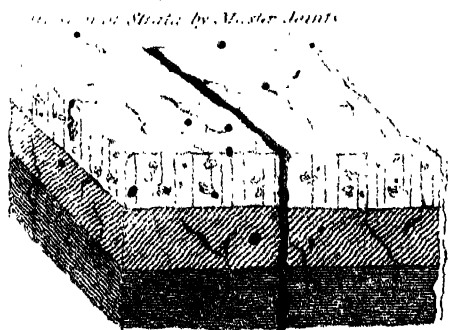
### *Uniformity of Stratification*



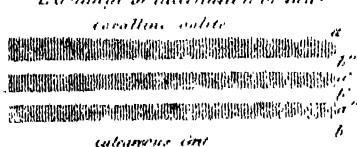
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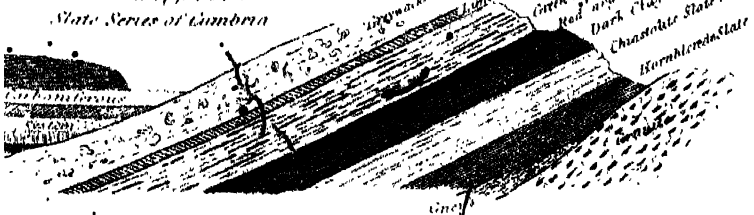
*et. v. n. et. Maria by, Master, Joana*



Exchange or alternation of Red:

*circulatore di Strada*

### Language of Note

*State Series of Numbers*

*Scotlan.2*





**GEOLOGY.**  
*Organic Remains.*

PL.

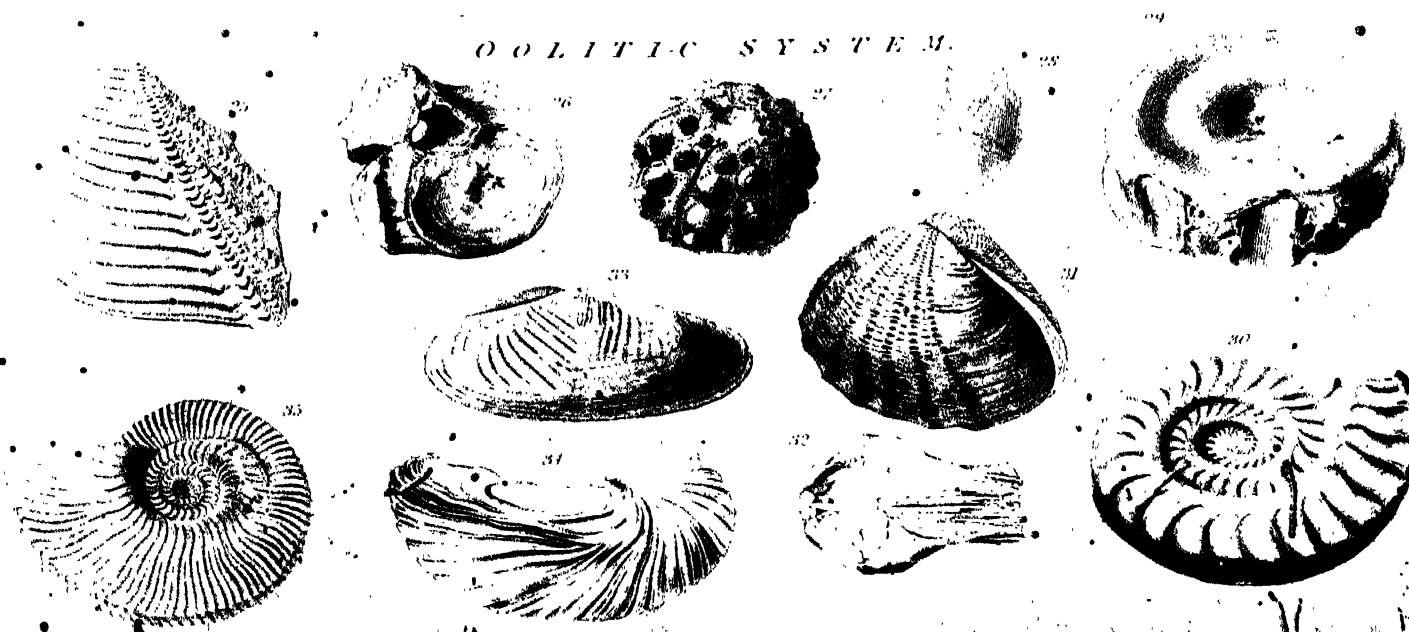
**TERTIARY SYSTEM.**



**CRETACEOUS SYSTEM.**

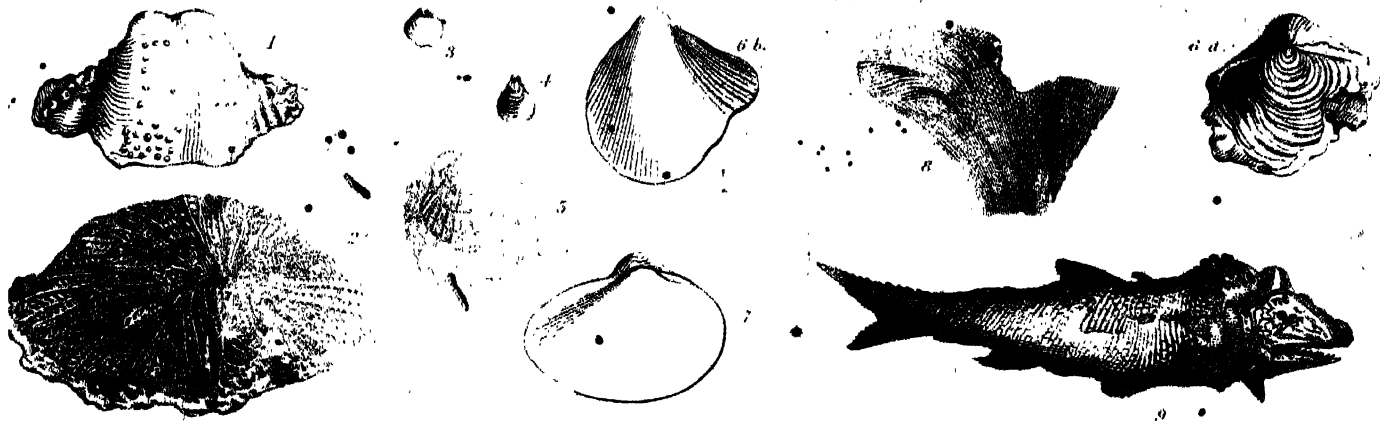


**OLIGOCENE SYSTEM.**

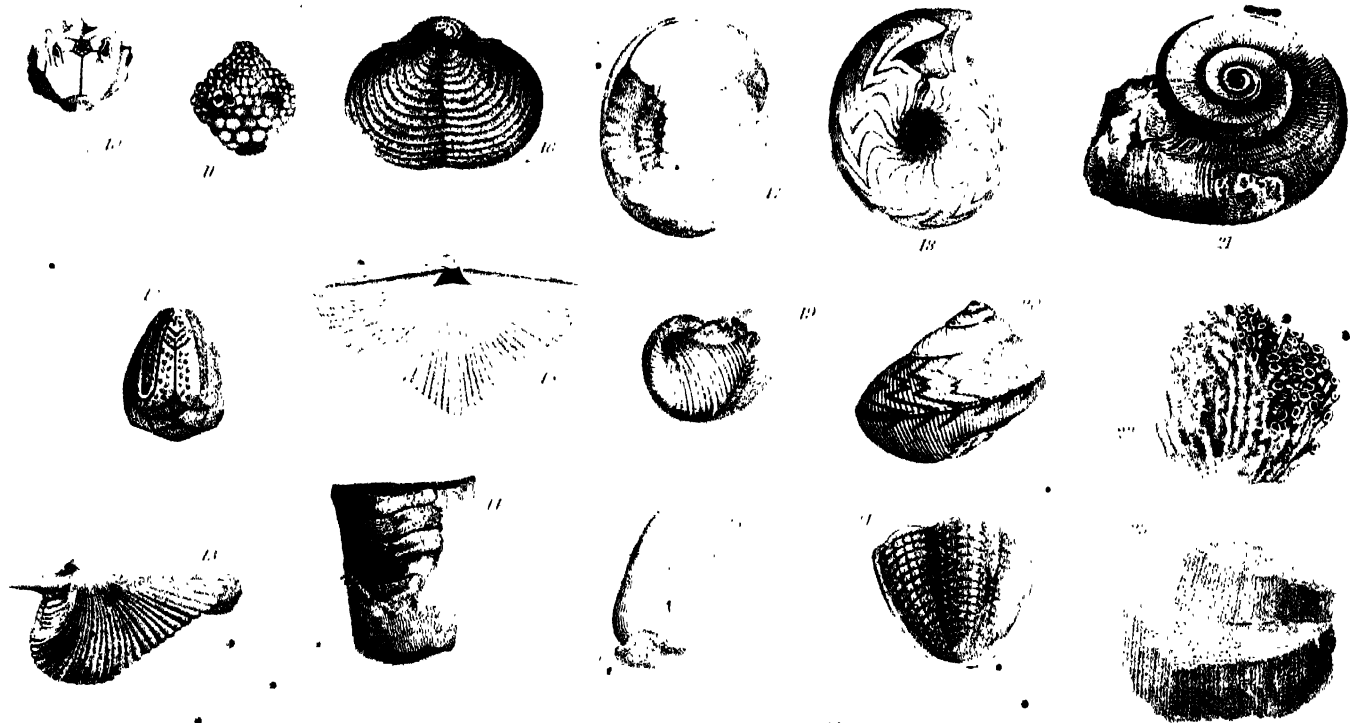




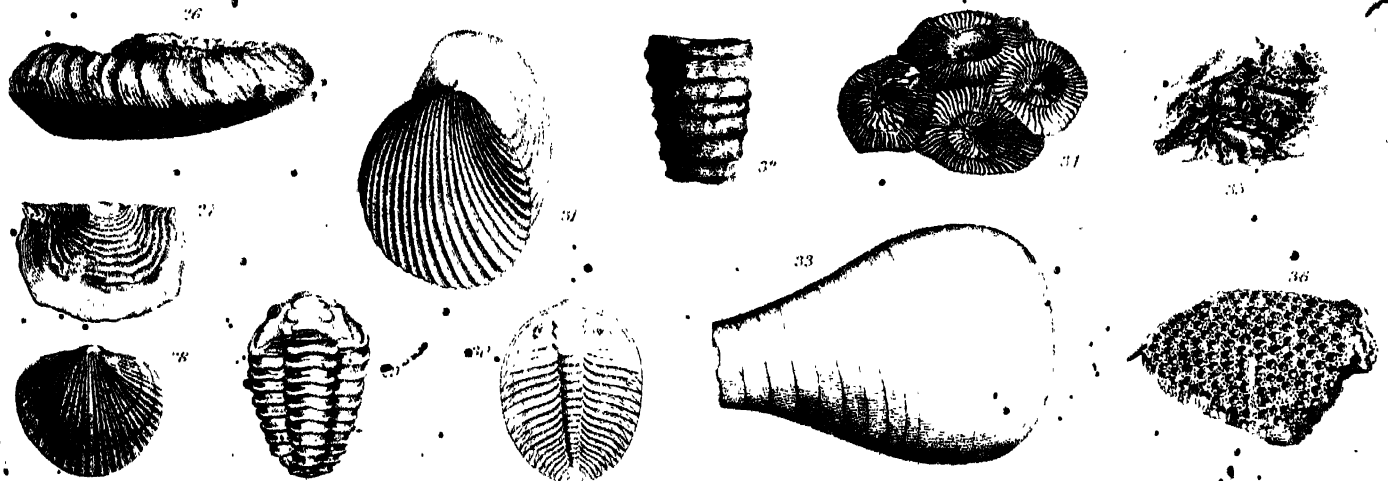
STRATIGRAPHY.  
*Cephalopod remains.*  
 SALIFEROUS SYSTEM



CARBONIFEROUS SYSTEM



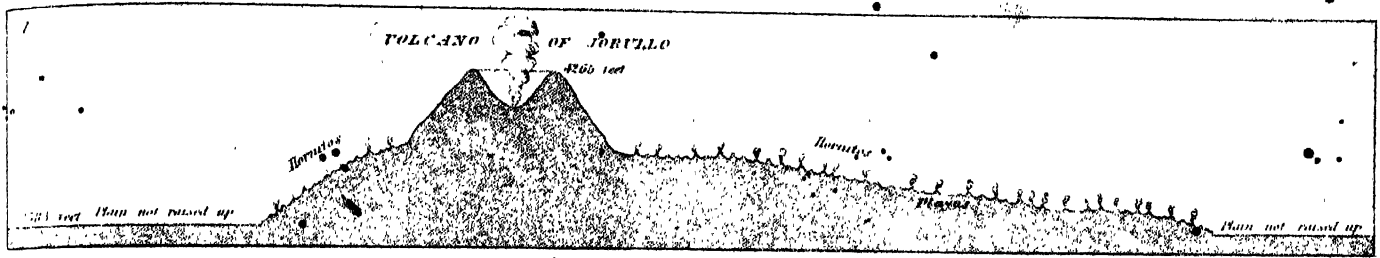
PRIMARY SYSTEM



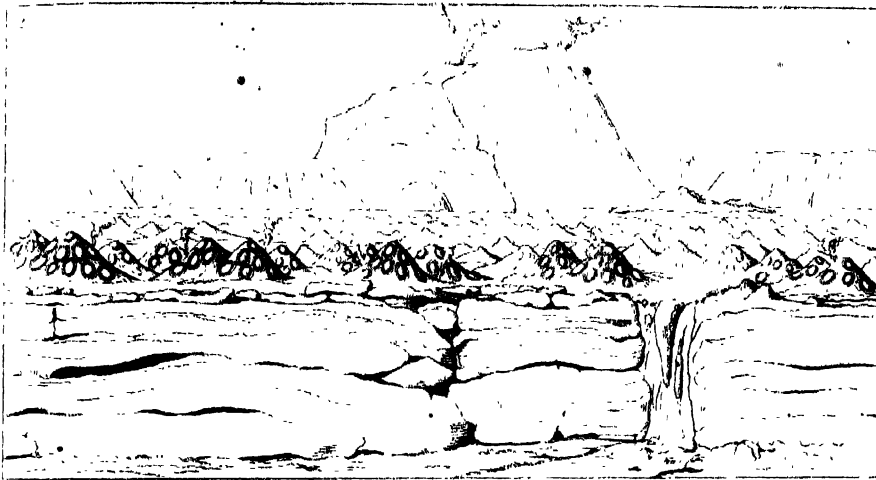


# GEOLOGY.

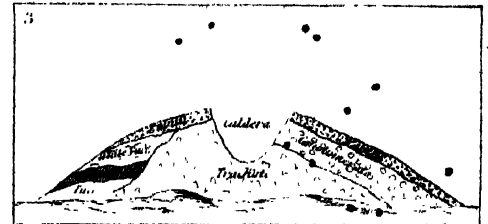
## Volcanoes.



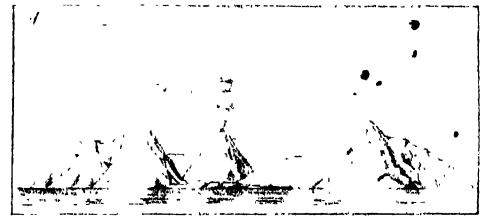
Section of Jorullo and the Altiplano.



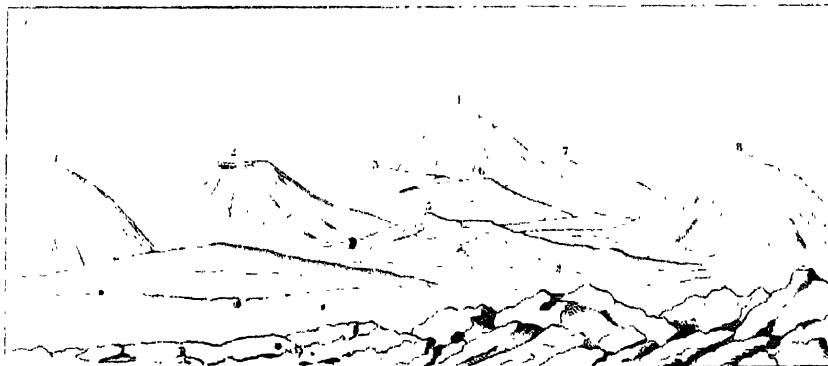
View of the Volcano of Jorullo Mexico.



Crater of Fuerteventura Island in the Canary.

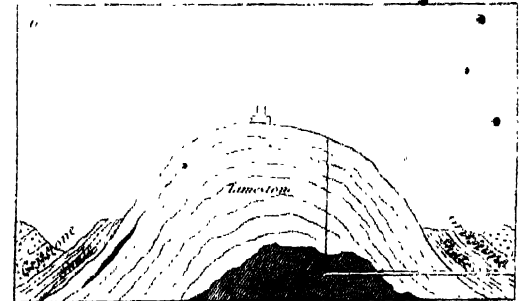


Crater of Fuerteventura Island in the Canary.

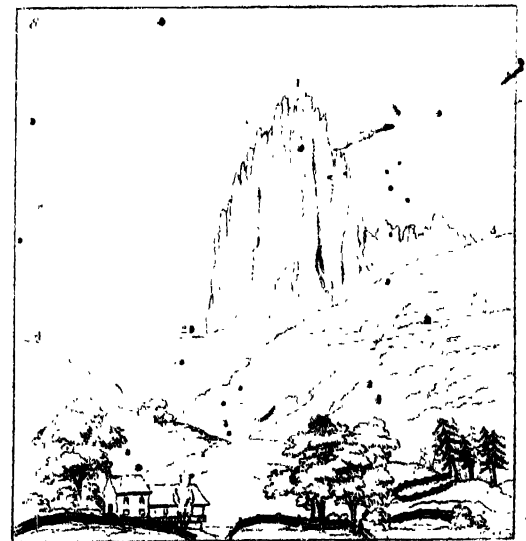
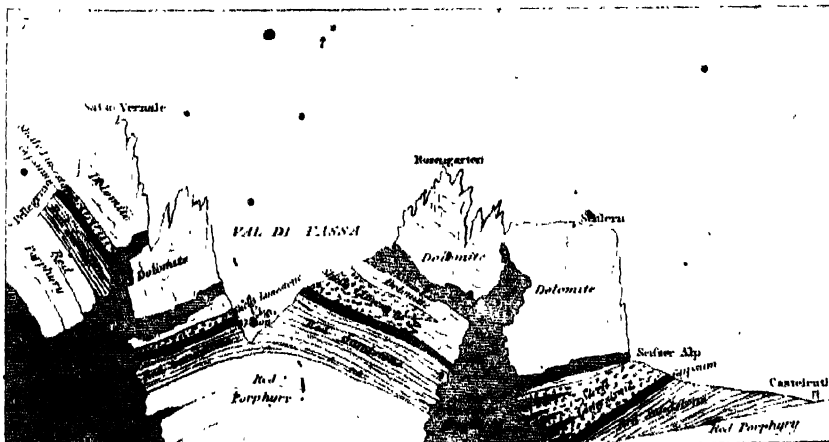


Trachyte Hills near Clermont in Auvergne seen from the Puy de la Vierge.

- |                      |                  |                     |
|----------------------|------------------|---------------------|
| 1. Grand Gouffre     | 4. Puy de Dome   | 7. Grand Souchet    |
| 2. Puy de la Vierge  | 5. Petit Souchet | 8. Puy de la Vierge |
| 3. Petit Puy de Dome | 6. Clermont      |                     |



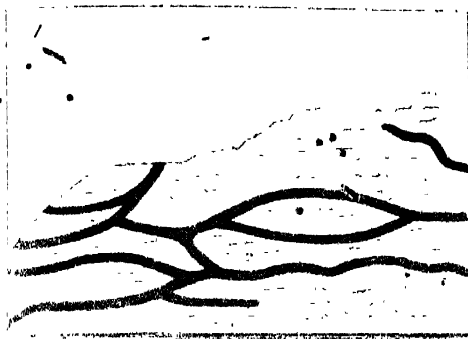
Section of Trach Hill near Clermont.



Trach Hill near Clermont. 1. Grand Gouffre 2. Puy de la Vierge 3. Petit Puy de Dome 4. Puy de Dome 5. Petit Souchet 6. Clermont 7. Grand Souchet 8. Puy de la Vierge



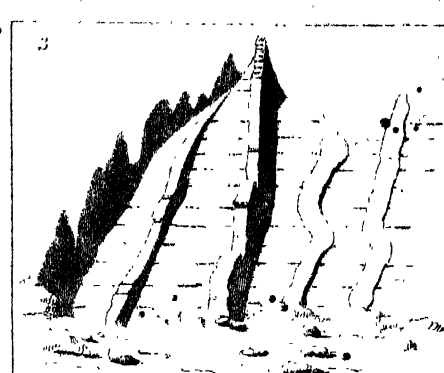




1. Im. penetrated by Dykes or Sluggish Lava, Stromboli



2. Im. penetrated by Dykes or Sluggish Lava, Stromboli



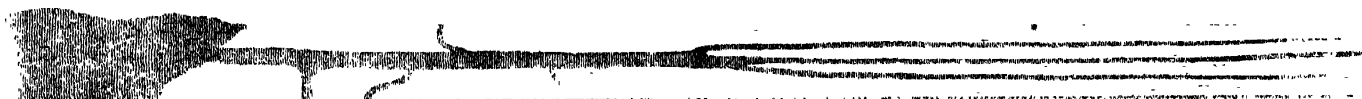
3. Dykes at the base of the Serie del Solizzo Etna



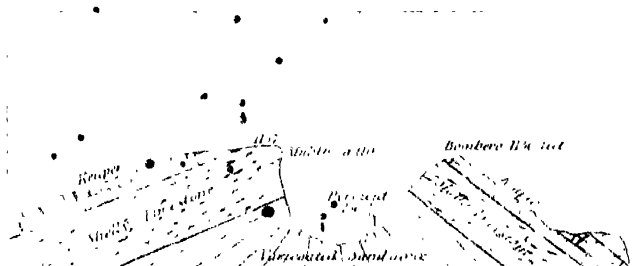
4. Dykes in Lava, Ponte A. Corvino



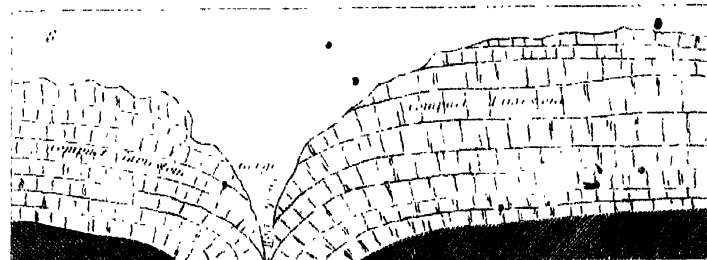
5. Dykes in Monte Somma, Vesuvius



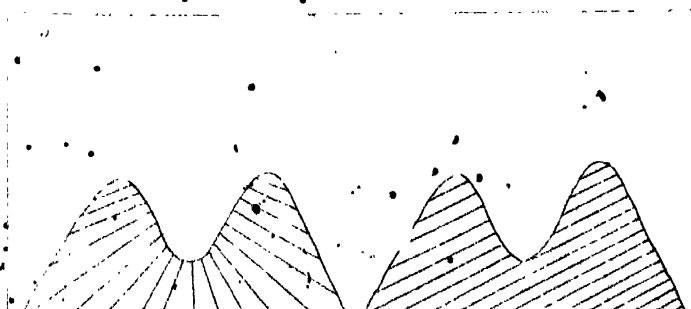
6. Dykes in Long, Limestone Ist. of Sicily



7. Section of the Crater Valley of Elevation, Parnassus

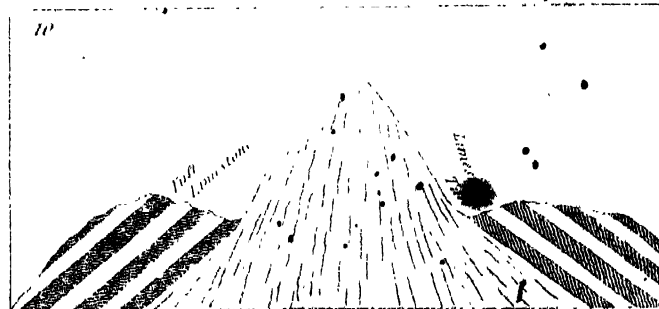


8. Section at St Paul de Fenouilhades, Dept. des Pyrénées Orient.



9. Valley formed out of a crater

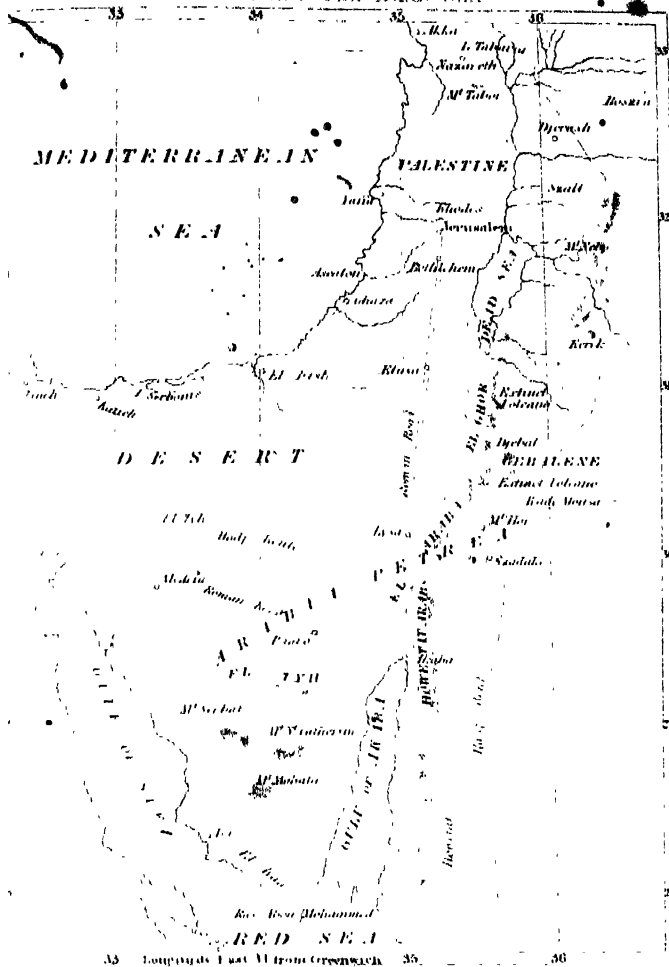
10. Valley formed by Denudation



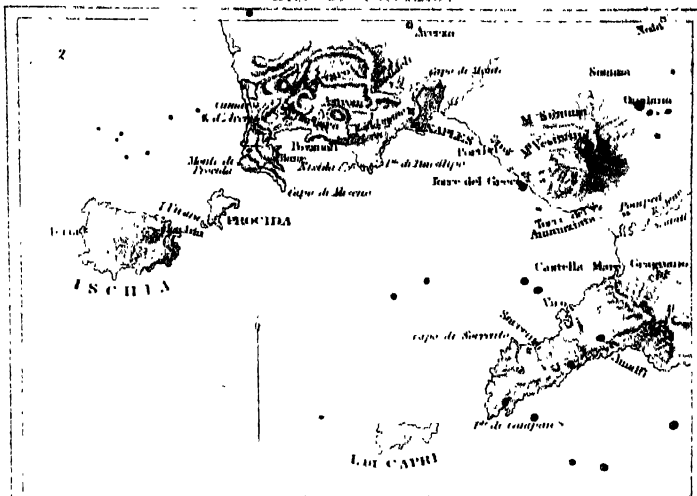
11. Trachyte Dome, Gieschenburg, Styria



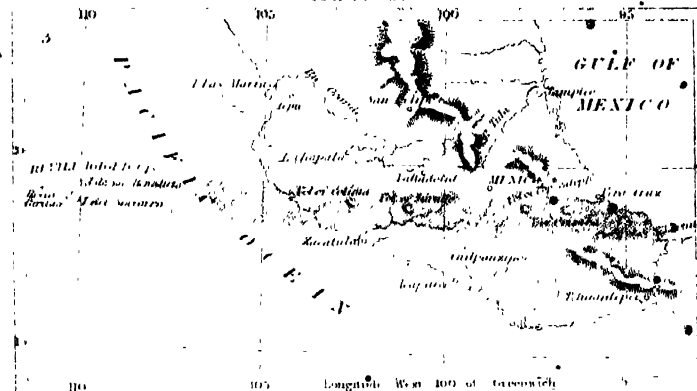
PALESTINE AND THE DEAD SEA



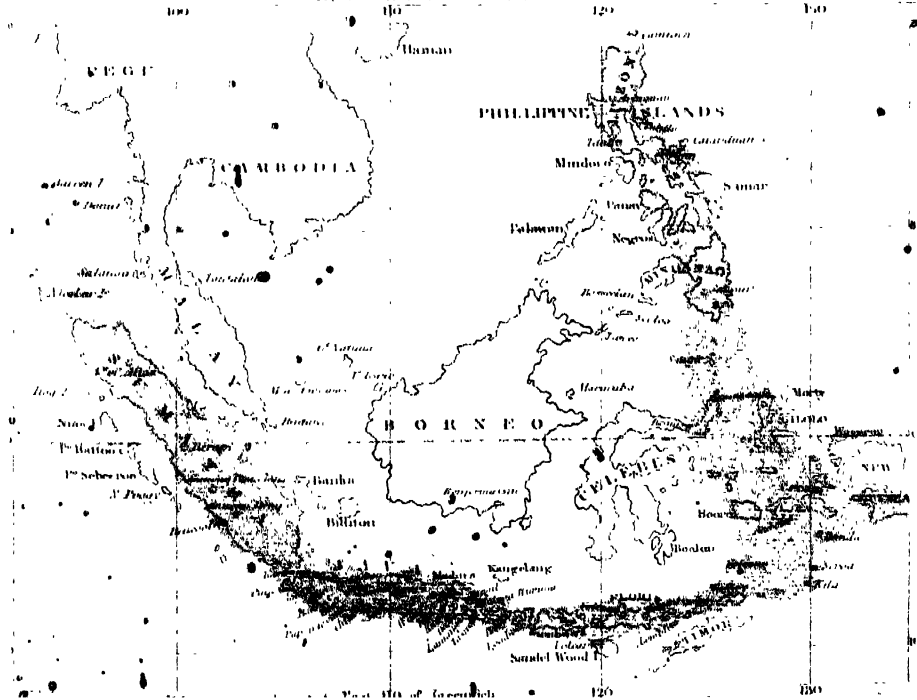
BAY OF NAPLES



MEXICO



VOLCANIC BAND OF THE MEDITERRANEAN



VOLCANIC BAND OF THE BULGARIAN ISLANDS

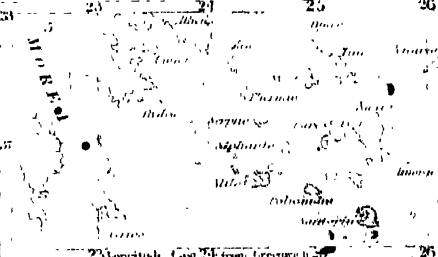


CHART & SECTION OF SANTORINI &c

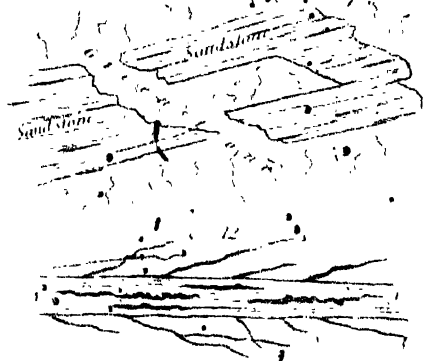
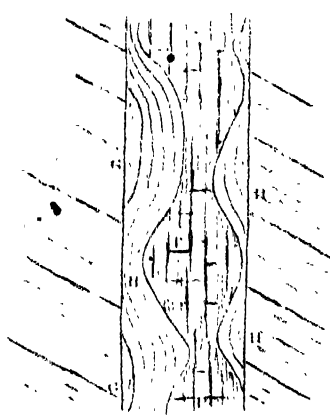
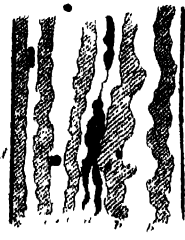
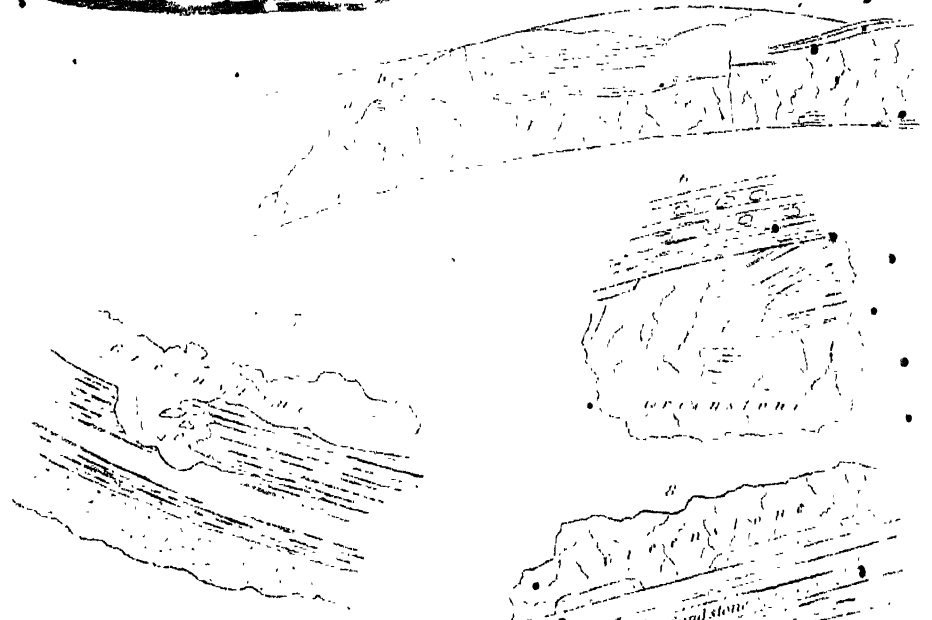
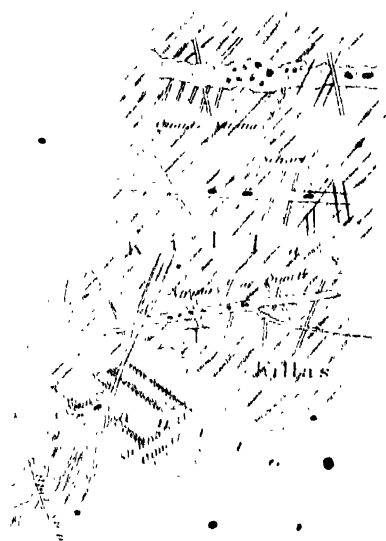
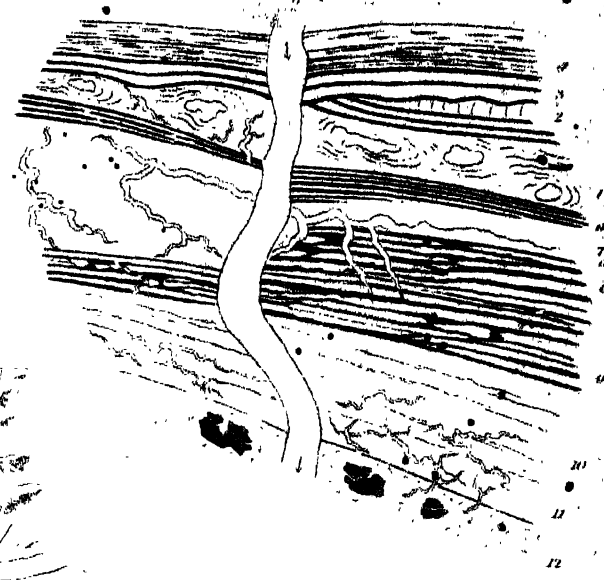
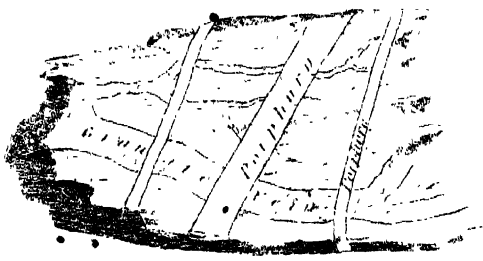
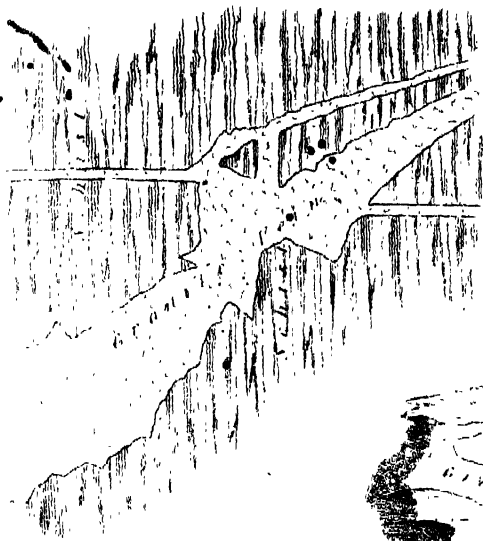




# GEOLOGY.

PLATE

Fig 1





# GEOLOGICAL MAP OF THE BRITISH ISLES.

constructed by

*Wm. Smith*

## EXPLANATION OF SIGNS

Tertiary Strata	
Cretaceous Strata	
Local deposit of the Weald	
Quaternary Strata	
Saliferous Strata	
Carboniferous Strata	
Primary Strata	
Granitic & Porphyritic Rocks	
Basaltic Rocks	

N O R T H

S E A

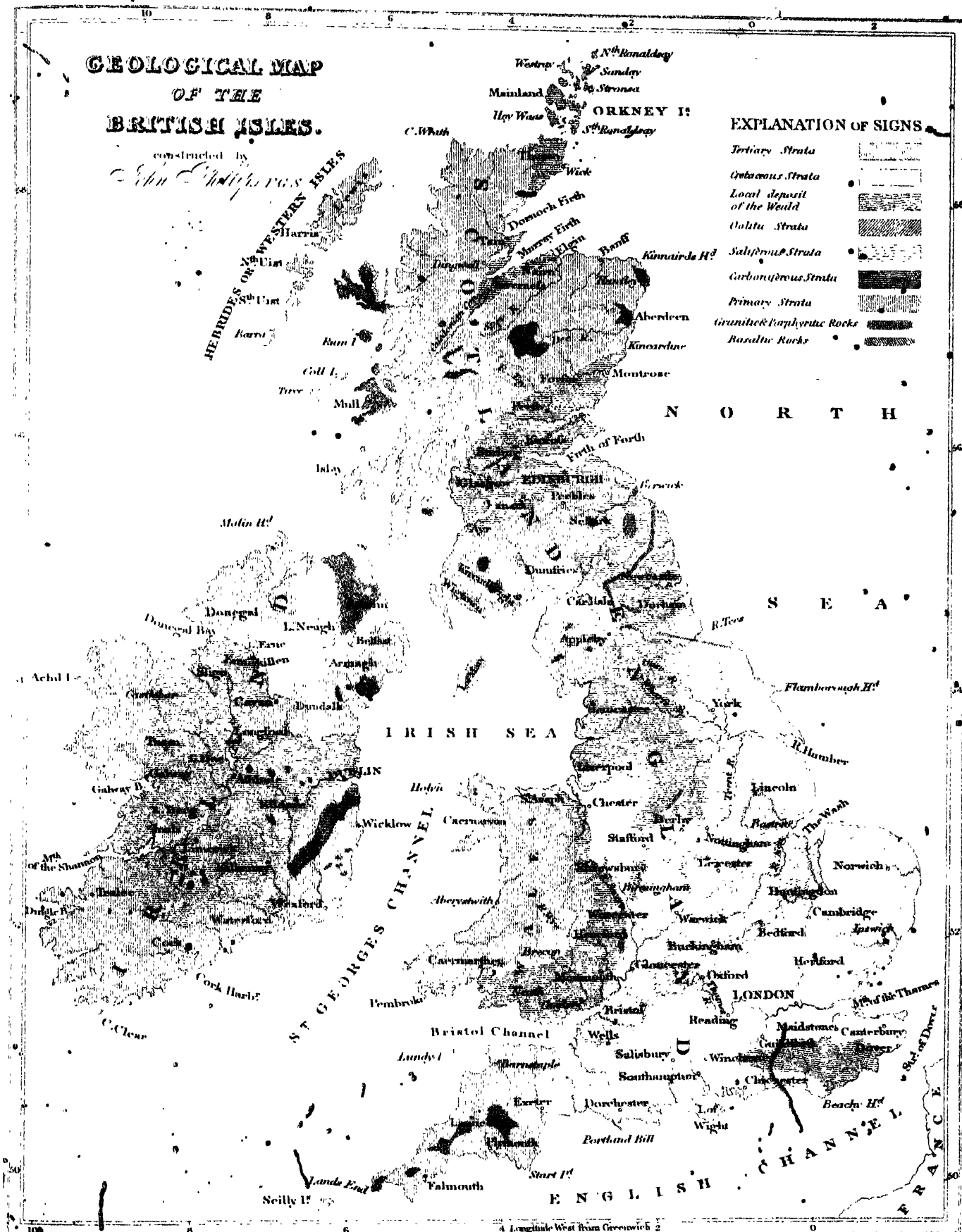
IRISH SEA

ST. GEORGES CHANNEL

E N G L I S H

C H A N N E L

F R A N C E







from various authorities by  
John Phillips Esq.



Premier &amp; Trautner Rocks

### *Secondary Strata*

Tertulian, itala

*Vélocité & Basses* - *Red*











